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Under contract to the Emission Control Technology Division of the U.S. Environmental Protection Agency, Technical Service Corporation (TSC) has compiled data, estimates and projections of vehicle population and use by vehicle age and type, for each of these cities: Chicago, Denver, Los Angeles, Houston, and Phoenix. Since motor vehicle emissions are sensitive to temperature, humidity, and barometric pressure, meterological data were also compiled.

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CHARACTERIZATION OF VEHICLE USE IN FIVE AIR QUALITY CONTROL REGIONS

Submitted in fulfillment of Task Order 4
U. S. EPA Contract 68-03-2392

30 March 1978

BY

John A. Eldon
Donald B. Hunsaker

Submitted to: Mr. Charles J. Domke
U. S. Environmental Protection Agency
Emission Control Technology Division
2929 Plymouth Road
Ann Arbor, Michigan 48105

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1.0 INTRODUCTION

Of the 247 Federal Air Quality Control Regions (AQCR) in the U.S., 39 are, or soon will be, in violation of Federal air quality standards. In urban areas, standards for three pollutants, hydrocarbons (HC), carbon monoxide (CO), and nitrogen oxides (NOx), are frequently violated. Since motor vehicle exhaust is a principal source of these three pollutants, it is important to estimate present and future automobile and truck population and usage in air pollution-prone urban areas. Because of changes in exhaust standards and vehicle deterioration, emissions are a function of vehicle age, and therefore, the total vehicle use must be characterized as a function of vehicle age.

Under contract to the Emission Control Technology Division of the U. S. Environmental Protection Agency, Technology Service Corporation (TSC) has compiled data, estimates, and projections of vehicle population and use by vehicle age and type, for each of five AQCR's: Chicago, Denver, Los Angeles, Houston, and Phoenix. Each of these regions is one in which ambient standards for one or more automotive pollutants are exceeded significantly.

Since motor vehicle emissions are sensitive to temperature, humidity, and barometric pressure, meteorological data for the five AQCR's were also compiled. To test the hypothesis that motor vehicle use or climate within a central urban core may differ from that of the region containing it, we also collected data for the metropolitan centers of four of the AQCR's, omitting Phoenix because of its uniformly low population density and near-absence of a traditional urban core.

TSC compiled eight sets of data on vehicle use, vehicle population and climate. These data sets and the assumptions and procedures used in their development are the subjects of Chapters 2 through 9 of the present report.

Chapter 2 presents projections of the ratio of urban to nonurban travel, for the years 1975 through 1990. The distinction between urban and nonurban travel within each AQCR is critical, because urban driving produces more HC and CO per mile than rural driving, and usually causes a heavier population exposure to air pollution.

Chapter 3 presents estimates of average individual vehicle use (miles driven per year) as a function of age and type.

Chapter 4 lists, for each of the AQCR's, distribution of vehicle registration by vehicle age. Again the data are separated by vehicle type, since vehicular life expectancy is a function of vehicle type (heavy-duty trucks, passenger cars, etc.).

Chapter 5 presents the distribution of total VMT in each AQCR by vehicle age and type. Given the vehicle emission factors as a function of age, and the total traffic load of a given roadway, the results in this chapter can be used to compute the corresponding total emissions.

Chapter 6 projects future trends in total vehicle miles traveled, for each of the five AQCR's. The total VMT in most AQCR's increases substantially, often by several percent per year, proportional to the growth in population, the ratio of cars to people, and the increase in the average use per vehicle.

Chapter 7 lists vehicle sales projections for each AQCR, based on national population and vehicle sales projections and an analysis of historical sales trends.

Finally, chapters 8 and 9 present temperature and absolute humidity data, respectively, for each AQCR. Monthly mean and average monthly range of temperature were compiled in Chapter 8, while monthly mean absolute humidity is the subject of Chapter 9. The monthly data were computed from ten-year averages of data for each calendar month.

This study was severely limited by the availability of data--in many cases, the desired data were nonexistant and had to be estimated from other information; this problem was especially severe for the data sets discussed in Chapters 2 through 7. The ratios of urban to nonurban travel discussed in Chapter 2 were not available by vehicle type for any of the AQCR's under study. In Chapter 3, the mileage accumulation data were based upon different data sets and time periods for automobiles and trucks. The Polk truck data used in Chapter 4 were not apportioned by fuel type, and trucks over 9 years old were not grouped by weight. The VMT in 1975 were not available by either age or vehicle type for the AQCR's of interest.

Most of the vehicle mile growth rates in Chapter 6 were based on national projections or guesses based on future use or sales.

Lastly, sales projections were given for the entire U.S. only and had to be estimated for the individual AQCR's, according to existing and projected populations. All of these areas of difficulty, together with the procedures and assumptions used to resolve the difficulties, are addressed in their respective chapters. The chapters also discuss the accuracy and reliability of the estimated data.

2.0 PROJECTED RATIO OF URBAN TO NONURBAN VMT, 1975-1990

Most AQCR's comprise both high-population-density urban areas and lower-density rural (nonurban) areas. The air pollution impact of motor vehicles, per vehicle mile traveled, is higher in the urban areas, for several reasons:

1) the higher frequency of stops in urban operation produces higher CO and HC emissions;

2) the higher speeds of rural driving generate lower concentrations and total amounts of HC and CO;

3) the total number of people exposed to automotive emissions increases with population density.

The need to differentiate between urban and nonurban operation of motor vehicles is a consequence of this difference in impacts.

The purpose of the present chapter is to estimate future trends in the relationship between urban and rural vehicle use, as a function of general vehicle type and location (AQCR of operation). Future changes in the ratio of urban to nonurban travel will reflect the growth of cities (particularly that of suburbs) and perhaps changes in driving habits (e.g., an increased popularity of long auto trips will tend to lower the urban/nonurban ratio).

2.1 DATA SOURCES

AQCR-specific estimates of the ratio of urban to nonurban VMT for all vehicle types combined are available from regional planning agencies, including the Southern California Association of Governments [1, 2], the Chicago Area Transportation Study [3], and the Houston- Galveston Regional Transportation Study. State-specific estimates of urban/nonurban ratio are also readily available [4].

The data sources listed above do not differentiate among the urban/nonurban ratios of different vehicle types. A breakdown of urban/nonurban ratio by vehicle type is available for the Wasatch Front, Utah [5]. Where appropriate, the Wasatch Front data have been applied to the AQCR's of interest, as explained in the next section.

2.2 PROCEDURES AND RESULTS

In most cases, the VMT estimates were derived from data for the corresponding state and from the more detailed Wasatch Front statistics.

For each of the five AQCR's, the 1973-1975 all vehicle urban/nonurban ratios for the corresponding state were compiled [4]. A linear regression of these data (the years and corresponding urban/nonurban ratios) was then used to generate estimates of urban/nonurban ratios for 1975 to 1990. The regression results comprise the bottom row of each of the tables.

For Denver, a separate estimate of the all-vehicle urban/nonurban ratio was provided by the Colorado State Highway Department [6].

The data sources listed above do not differentiate among the urban/nonurban ratios of different vehicle types. A breakdown of urban/nonurban ratio by vehicle type is available for the Wasatch Front, Utah [5]. Where appropriate, the Wasatch Front data have been applied to the AQCR's of interest, as explained in the next section.
all-vehicle uban/nonurban VMT ratio divided by the Wasatch Front's all-vehicle urban/nonurban VMT ratio. The weighting factors are listed below the respective urban/nonurban VMT tables 2.1 through 2.5.

2.3 LIMITATIONS OF THE ANALYSIS

Uncertainties in the data tend to limit the precision of the

analyses. It is worthwhile, therefore to note possible causes of these uncertainties so that, at best, qualitative assessments can be made (i.e., the likelihood of over-or-underestimating results).

In regards to the previous findings, the urban/nonurban VMT ratio of any given AQCR was assumed to be equivalent to the state containing it. The Utah urban/nonurban ratios (the Wasatch Front) were the only existing estimates of urban/nonurban VMT ratios which were itemized by vehicle type. The same ratio by vehicle type was applied to all AQCR's. Barring abrupt economic, sociological, or fuel supply changes, these projections should prove fairly accurate.

Table 2.1. Ratio of Urban/Nonurban Travel by year for Chicago AQCR

YEAR VEHICLE TYPE	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1990
PASSENGER CARS *	2.33	2.36	2.40	2.44	2.48	2.52	2.56	2.60	2.64	2.68	2.72	2.92
LIGHT-DUTY TRUCKS *	1.55	1.58	1.60	1.65	1.68	1.68	1.70	1.73	1.75	1.78	1.80	1.93
HEAVY-DUTY TRUCKS *	0.75	0.76	0.77	0.78	0.79	0.80	0.81	0.81	0.82	0.83	0.84	0.88
ALL VEHICLES	2.02	2.03	2.06	2.10	2.13	2.17	2.21	2.24	2.28	2.31	2.35	2.53

*Data are result of linear regression performed on adjusted Utah statewide data for 1973, 1974, and 1975 [5]. The ratio of urban/nonurban (u/n) ratios for Utah and Illinois was 1:1.7; thus, all Utah values were multiplied by 1.7 to obtain Illinois values.

Table 2.2. Ratio of Urban/Nonurban Travel by Year for Denver Metropolitan Region

YEAR VEHICLE TYPE	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1990
PASSENGER CARS*	6.03	6.12	6.24	6.35	6.46	6.57	6.68	6.79	6.90	7.01	7.12	7.67
LIGHT-DUTY TRUCKS*	7.00	4.09	4.15	4.21	4.28	4.34	4.41	4.47	4.54	4.60	4.67	4.99
HEAVY-DUTY TRUCKS*	1.94	1.98	1.99	2.01	2.03	2.05	2.07	2.09	2.11	2.13	2.15	2.25
ALL VEHICLES	4.9	4.8	4.7	4.6	4.6	4.5	4.4	4.4	4.2	4.2	4.1	3.8

*The ratio of u/n ratios for Utah and Denver was 1:4.4; thus, all Utah values were multiplied by 4.4 to obtain Denver values.

Table 2.3. Ratio of Urban/Nonurban travel by Year for Houston AQCR

YEAR VEHICLE TYPE	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1990
PASSENGER CARS*	4.11	4.17	4.25	4.32	4.40	4.48	4.55	4.62	4.70	4.78	4.85	5.22
LIGHT-DUTY TRUCKS*	2.73	2.79	2.83	2.88	2.92	2.97	3.01	3.06	3.10	3.14	3.19	3.42
HEAVY-DUTY TRUCKS*	1.32	1.35	1.36	1.38	1.39	1.41	1.42	1.44	1.45	1.46	1.48	1.56
ALL VEHICLES	3.45	3.35	3.32	3.30	3.27	3.25	3.23	3.21	3.20	3.16	3.14	3.02

*The ratio of u/n ratios for Utah and Texas was 1:3; thus, all Utah values were multiplied by 3.0 to obtain Texas statewide values.

Table 2.4. Ratio of Urban/Nonurban Travel by Year for Los Angeles AQCR

YEAR VEHICLE TYPE	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1990
PASSENGER CARS*	3.01	3.06	3.12	3.17	3.23	3.28	3.34	3.39	3.45	3.50	3.56	3.83
LIGHT-DUTY TRUCKS*	2.00	2.05	2.08	2.12	2.15	2.18	2.22	2.26	2.29	2.32	2.36	2.54
HEAVY-DUTY TRUCKS*	0.97	0.99	1.00	1.01	1.02	1.03	1.04	1.05	1.06	1.07	1.08	1.14
ALL VEHICLES	2.51	2.57	2.70	2.82	2.95	3.08	3.21	3.34	3.47	3.59	3.72	4.37

*The ratio of u/n ratios for Utah and California was 1:2.2; thus, all Utah values were multiplied by 2.2 to obtain California statewide values.

Table 2.5. Ratio of Urban/Nonurban Travel by Year for Phoenix AQCR

YEAR VEHICLE TYPE	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1990
PASSENGER CARS*	1.37	1.39	1.42	1.44	1.47	1.49	1.52	1.54	1.57	1.59	1.62	1.74
LIGHT-DUTY TRUCKS*	0.91	0.93	0.94	0.96	0.97	0.99	1.00	1.02	1.03	1.05	1.06	1.14
HEAVY-DUTY TRUCKS*	0.44	0.45	0.45	0.46	0.46	0.47	0.47	0.48	0.48	0.49	0.49	0.52
ALL VEHICLES	1.12	1.19	1.25	1.31	1.36	1.42	1.48	1.54	1.60	1.65	1.71	2.00

*The ratio of u/n ratios for Utah and Arizona was 1:1.

2.4 REFERENCES

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2. Southern California Association of Governments, "Transportation Study - Phase One" March 1973, Documentation Report Series, DR/1.

3. Personal Communication: Biedron, Emil, of the Chicago Area Transportation Study, Chicago, Illinois, 1978.

4. Motor Vehicle Manufacturers' Association, "MVMA Motor-Vehicle Facts and Figures," 1972, p. 49; 1975, p. 47; 1976, p. 69; 1977 p. 61.

5. Crandall, Mick, Assistant Director of Technical Services, Wasatch Front Regional Council, Salt Lake City, Utah. Personal communication, January 1978.

6. Fritz, Glenn, Colorado State Highway Department, Denver, Colorado. Personal communication, January 1978.

3.0 MILEAGE ACCUMULATION BY VEHICLE AGE AND TYPE

Mechanical deterioration and historical changes in new-vehicle emission standards cause vehicles of different ages to exhibit dissimilar emissions per mile driven. To estimate total mobile source emissions accurately, it is necessary to estimate average vehicle usage (vehicle miles traveled (VMT) per year per vehicle) as a function of vehicle age, for each AQCR. Average usage was computed separately for each major category of vehicle: automobiles, light duty gasoline trucks, heavy duty gasoline trucks, heavy duty diesel trucks, and motorcycles. The data show that the annual use of a vehicle tends to decrease with age and the rate at which vehicle use decreases with age is a function of location and vehicle type, reflecting numerous sociological, economic, and climatological factors.

3.1 DATA SOURCES

Of the several available sources of automobile use data, the primary source used was the EPA's in-use vehicle emission testing (surveillance) program, in which the test date, model year, and odometer reading of each tested vehicle were recorded [1]. Estimates of typical automobile use by age and location were generated from a regression analysis of these data.

Due to practical testing considerations and differences in emission laws, trucks are generally not included in the emission surveillance program. However, the Census Bureau periodically publishes estimates of truck use, based on questionnaire survey results [2]. The survey collects information on truck weight, state of registration, model year, fuel type, and annual VMT.

Two additional data sources are also available. Several states,

including California, have operated vehicle safety testing programs, during which the test date, model year, and odometer reading of each vehicle are recorded. From these data, the California Air Resources Board has generated estimates of vehicle miles traveled versus age for California cars [3]. Vehicle use estimates have also been published in various transportation studies, sponsored by EPA and by local planning agencies [4]. Most of these studies have been based on a 1967 survey of national vehicle use, which was conducted by the Department of Commerce [5]. This study, now outdated, contains only national vehicle use figures and is less reliable for conducting analyses. As such, it was not used in the present analysis.

The only comprehensive source of motorcycle use data is the EPA-sponsored "Gallup Survey" [6]. This survey, based on questionnaires sent to motorcycle owners across the U.S., includes information on the average use of motorcycles by age and engine size. Data are given only for Los Angeles, plus a few regions not studied here.

To assure the utilization of only the best available data, the automotive use estimates presented here were based exclusively on the EPA surveillance testing, the truck use estimates on the Census Bureau survey, and the motorcycle use estimates on the Gallup Survey.

3.2 PROCEDURE

TSC's automotive use estimates are based on data from the EPA's in-use vehicle emission surveillance testing program. For each of the five AQCR's, the test dates, model years, and odometer readings of at least 500 vehicles were summarized and analyzed. A regression was performed between odometer reading (cumulative mileage) and vehicle age

(estimated from the test date and the model year).

Two problems were encountered in the regression analysis. First, while the cumulative VMT of each vehicle is usually accurately represented by its odometer reading, the age of the vehicle must be estimated from the test date and model year. Since cars of any given model year are sold between October of the preceding year and September of the model year, the age of each car in the test is know only to ± 6 months. The second problem is the shortage or absence of older cars (over 9 years of age) in the data base. This is a consequence of the EPA's policy that the distribution of ages and models within the vehicle test group for each AQCR should reflect that of the local vehicle population.

The first problem was addressed by assuming that sales of vehicles of model year "M" are uniform over the interval (M-.25) to (M+.75), i.e., between 1 October of the year (M-1) and 30 September of the year M. (The exact annual sales pattern has only a slight impact on the regression results.)

To allow for the known decrease in average annual vehicle use with increasing age [3,5], a log-linear regression was used, viz:

$$\log (VMT) = a + b \cdot LOG (AGE), \qquad (1)$$

where VMT is the cumulative odometer reading of the vehicle, AGE is the estimated age of the vehicle when tested, and "a" and "b" are constants of regression. In the regression, the use of log (AGE) instead of age reflects the fact that the rate of decrease of annual VMT with age will be smaller for older vehicles than for newer vehicles. The AGE is the test date minus the middle date of the model year, viz:

$$AGE = TD - (M + .25), \qquad (2)$$

where tD is the test date in years and (M+.25) is approximately 1 April of the year "M". This regression yields an expression of the form:

$$VMT = k \cdot (AGE)^b, \text{ where } k = e^a. \quad (3)$$

To improve the fit of the regression to the actual data, a second term was added to the regression, giving an equation of the form:

$$\log (VMT) = a + b \cdot \log(AGE) + c \cdot [\log(AGE)]^2 \quad (4)$$

A third problem in the data analysis, a consequence of the first problem, is that the ages of new vehicles (less than two years old) cannot be estimated accurately, due to the six-month uncertainty in the age of every vehicle tested. A six-month error in age estimation is clearly more significant among two-year-old cars than among twelve-year-old cars. Therefore, all cars having calculated ages of less than .75 years were deleted from the data base. The choice of a .75-year cut-off represents a compromise between accepting all high-uncertainty data and eliminating too much new-car data.

Using the regression equation (based on data for all cars of greater than .75 years apparent age) for each AQCR, the final step was to compute the predicted VMT for each age of vehicle. The latest-year annual VMT of a four-year-old car, e.g., is the cumulative odometer reading predicted for four-year old cars minus that predicted for three-year old cars.

Truck use estimates were extracted from the 1972 Bureau of the Census truck survey [2]. This publication lists truck counts and reported annual use (VMT) by truck age, type, weight, and state of registration. Truck use statistics for each AQCR were assumed to equal those given for the state containing it. This publication does not divide annual truck usage data into the specific categories of

interest, namely: light duty gasoline trucks, light duty diesel trucks, heavy duty gasoline trucks, and heavy duty diesel trucks. However, it does give separate use estimates for "all trucks excluding pickups and panels" and for "all trucks." By assuming that "all trucks excluding pickups and panels" is roughly synonymous with "heavy duty trucks", the average annual use per truck for light duty trucks and for heavy duty trucks can be estimated. Given the total populations and the total annual VMT of all trucks and of heavy trucks (actually "all trucks excluding pickups and panels"), we computed the annual VMT of light trucks, using the expression:

$$VMT(LDT) = \frac{M(T) - M(HDT)}{P - P(HDT)} \qquad (5)$$

where VMT(LDT) is the estimated annual use of light trucks, per truck, M(T) is the total combined annual mileage of all trucks, M(HDT) is the combined mileage of heavy duty trucks, P is the total population of all trucks, and P(HDT) is the total count of heavy duty trucks. All of the mileage and populations are specific to each state and vehicle age listed.

In order to estimate the average annual use of gasoline versus diesel trucks within each AQCR, the average ratio of diesel truck to gasoline truck usage for each age of truck was assumed to be the same as the AQCR average for all ages of trucks combined. Although the heavy construction of diesel engines implies that diesel truck use declines more slowly with cumulative VMT then gasoline truck use, the

faster mileage accumulation of diesels compensates, resulting in similar diesel and gasoline truck life expectancies.

Since the questionnaire survey results are given for pairs of model years, the table entries for pairs of adjacent truck ages are the same. To avoid introducing errors by smoothing the data, the data were left "clustered" by pairs of model years.

Finally, the motorcycle use figures were extracted from the Gallup Survey, without modification. "Warm climate" estimates were applied to the Los Angeles, Houston, and Phoenix AQCR's, while national average figures were used for Chicago and Denver.

3.3 RESULTS OF THE ANALYSIS

Tables 3.1 through 3.5 present estimates of vehicle use by vehicle type, age, and location. The analysis and presentation are restricted to the five AQCR's. Vehicle use in metropolitan zones was assumed to parallel that in the AQCR's, i.e., the metropolitan zones with the heaviest use of older cars will lie within AQCR's with heavy older car use.

Estimates of vehicle use are highest in the mild-climate, "urban-sprawled" AQCR's of Los Angeles, Phoenix, and Houston, and lowest in the denser, colder Chicago area. In all cases, the average VMT figures pertain to total use of vehicles registered in the AQCR of interest, rather than to the total use of all vehicles (regardless of registry) within the AQCR. For example, the entry of 8800 miles per year for new cars in Chicago means that new cars registered within that AQCR are operated an average of 8800 miles per year, not necessarily all within the AQCR itself. Indeed, long-haul trucks (mainly heavy duty diesels) are driven primarily outside of the AQCR in which they

TABLE 3.1 MILEAGE ACCUMULATION BY VEHICLE AGE AND TYPE - CHICAGO AQCR

(Thousands of Miles Per Year)

	Age (years)																				
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Passenger cars	8.8	10.7	9.6	8.7	7.9	7.2	6.7	6.2	5.8	5.4	5.1	4.8	4.5	4.3	4.0	3.8	3.7	3.5	3.3	3.2	3.1
Trucks	18.3	18.3	15.9	15.9	12.0	12.0	9.7	9.7	8.8	8.8	4.8	4.8									
light duty trucks	14.7	14.7	12.6	12.6	8.7	8.7	7.9	7.9	8.5	8.5	4.9	4.9									
gasoline LDT	14.7	14.7	12.6	12.6	8.7	8.7	7.9	7.9	8.5	8.5	4.9	4.9									
diesel LDT*	-	-	-	-	-	-	-	-	-	-	-	-									
heavy duty trucks	31.4	31.4	24.3	24.3	16.9	16.9	13.1	13.1	9.5	9.5	4.8	4.8									
gasoline HDT	22.0	22.0	17.0	17.0	11.8	11.8	9.2	9.2	6.6	6.6	3.4	3.4									
diesel HDT	97.5	97.5	75.4	75.4	52.5	52.5	40.7	40.7	29.5	29.5	15.2	15.2									
street motorcycles	2.3	2.1	1.8	1.7	1.5	1.3	1.7	1.0	0.9	0.8	0.7	0.0									
<170 cc	1.3	1.3	1.2	1.1	1.1	1.0	1.0	0.9	0.8	0.8	0.8	0.7									
≥170 cc	3.7	3.2	2.7	2.3	1.9	1.6	1.4	1.1	1.0	0.8	0.7	0.6									

*The diesel LDT population is too small to permit a reliable assessment of diesel LDT usage.

TABLE 3.2 MILEAGE ACCUMULATION BY VEHICLE AGE AND TYPE - DENVER

(Thousands of Miles Per Year)

Age (years)

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Passenger cars	9.5	11.5	10.4	9.6	8.8	8.2	7.6	7.2	6.7	6.4	6.0	5.7	5.5	5.2	5.0	4.8	4.6	4.4	4.3	4.1	4.0
Trucks	17.5	17.5	15.9	15.9	11.7	11.7	12.8	12.8	7.8	7.8	7.4	7.4									
light duty trucks	15.0	15.0	13.3	13.3	10.7	10.7	12.2	12.2	7.3	7.3	8.1	8.1									
gasoline LDT	15.0	15.0	13.3	13.3	10.7	10.7	12.2	12.2	7.3	7.3	8.1	8.1									
diesel LDT *	-	-	-	-	-	-	-	-	-	-	-	-									
heavy duty trucks	29.0	29.0	31.2	31.2	17.7	17.7	15.0	15.0	9.3	9.3	5.7	5.7									
gasoline HDT	16.1	16.1	17.3	17.3	9.8	9.8	8.3	8.3	5.1	5.1	3.2	3.2									
diesel HDT	96.9	96.9	104.2	104.2	59.1	59.1	50.1	50.1	31.1	31.1	19.0	19.0									
street motorcycles	2.3	2.1	1.8	1.7	1.5	1.3	1.7	1.0	0.9	0.8	0.7	0.0									
< 170 cc	1.3	1.3	1.2	1.1	1.1	1.0	1.0	0.9	0.8	0.8	0.8	0.7									
≥ 170 cc	3.7	3.2	2.7	2.3	1.9	1.6	1.4	1.1	1.0	0.8	0.7	0.6									

*Diesel LDT sample size too small.

TABLE 3.3 MILEAGE ACCUMULATION BY VEHICLE AGE AND TYPE - HOUSTON

(Thousands of Miles Per Year)

Age (years)

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Passenger cars	13.4	13.8	11.7	10.3	9.2	8.4	7.7	7.1	6.5	6.1	5.7	5.4	5.1	4.8	4.6	4.3	4.1	3.9	3.8	3.6	3.4
Trucks	21.2	21.2	18.4	18.4	15.1	15.1	13.1	13.1	9.8	9.8	8.4	8.4									
light duty trucks	18.4	18.4	15.2	15.2	13.4	13.4	12.0	12.0	9.4	9.4	8.5	8.5									
gasoline LDT	18.3	18.3	15.2	15.2	13.4	13.4	12.0	12.0	9.4	9.4	8.5	8.5									
diesel LDT	23.7	23.7	19.7	19.7	17.4	17.4	15.5	15.5	12.2	12.2	11.0	11.0									
heavy duty trucks	33.2	33.2	34.3	34.3	23.7	23.7	19.9	19.9	11.8	11.8	8.0	8.0									
gasoline HDT	20.7	20.7	21.4	21.4	14.8	14.8	12.4	12.4	7.4	7.4	5.0	5.0									
diesel HDT	91.4	91.4	94.4	94.4	65.3	65.3	54.8	54.8	32.5	32.5	22.0	22.0									
street motorcycles	4.8	3.8	3.1	2.5	2.0	1.6	1.3	1.0	0.8	0.6	0.5	0.4									
< 170 cc	2.4	1.9	1.6	1.2	1.0	0.8	0.6	0.5	0.4	0.3	0.3	0.2									
≥ 170 cc	6.8	5.4	4.4	3.5	2.7	2.2	1.8	1.4	1.1	0.9	0.7	0.6									

TABLE 3.4 MILEAGE ACCUMULATION BY VEHICLE AGE AND TYPE - LOS ANGELES

(Thousands of Miles Per Year)

Age (years)

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Passenger cars	12.6	13.8	11.3	9.4	8.0	6.9	6.1	5.3	4.7	4.2	3.8	3.4	3.1	2.8	2.6	2.4	2.2	2.0	1.8	1.7	1.5
Trucks	20.5	20.5	17.4	17.4	12.5	12.5	11.2	11.2	15.9	15.9	8.8	8.8									
light duty trucks	17.9	17.9	14.8	14.8	10.6	10.6	9.9	9.9	15.1	15.1	7.8	7.8									
gasoline LDT	17.8	17.8	14.7	14.7	10.5	10.5	9.8	9.8	15.0	15.0	7.7	7.7									
diesel LDT	30.2	30.2	25.0	25.0	17.9	17.9	16.7	16.7	25.5	25.5	13.2	13.2									
heavy duty trucks	30.9	30.9	28.2	28.2	24.0	24.0	18.0	18.0	19.7	19.7	11.6	11.6									
gasoline HDT	19.6	19.6	17.9	17.9	15.3	15.3	11.4	11.4	12.5	12.5	7.4	7.4									
diesel HDT	79.0	79.0	72.1	72.1	61.3	61.3	46.0	46.0	50.3	50.3	29.6	29.6									
street motorcycles	4.8	3.8	3.1	2.5	2.0	1.6	1.3	1.0	0.8	0.6	0.5	0.4									
>170 cc	2.4	1.9	1.6	1.2	1.0	0.8	0.6	0.5	0.4	0.3	0.3	0.2									
≤170 cc	6.8	5.4	4.4	3.5	2.7	2.2	1.8	1.4	1.1	0.9	0.7	0.6									

TABLE 3.5 MILEAGE ACCUMULATION BY VEHICLE AGE AND TYPE - PHOENIX

(Thousands of Miles Per Year)

Age (years)

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Passenger cars	12.1	11.4	10.2	9.5	9.0	8.5	8.2	7.9	7.6	7.3	7.1	6.9	6.8	6.6	6.5	6.3	6.2	6.1	6.0	5.9	5.8
Trucks	20.0	20.0	15.9	15.9	11.3	11.3	12.0	12.0	13.2	13.2	7.3	7.3									
light duty trucks	17.4	17.4	14.6	14.6	10.5	10.5	11.3	11.3	12.5	12.5	6.7	6.7									
gasoline LDT	17.4	17.4	14.6	14.6	10.5	10.5	11.3	11.3	12.5	12.5	6.7	6.7									
diesel LDT	10.3	10.3	8.7	8.7	6.2	6.2	6.6	6.6	7.4	7.4	4.0	4.0									
heavy duty trucks	38.7	38.7	30.6	30.6	17.5	17.5	18.9	18.9	15.5	15.5	9.6	9.6									
gasoline HDT	22.8	22.8	18.0	18.0	10.3	10.3	11.1	11.1	9.1	9.1	5.6	5.6									
diesel HDT	100.4	100.4	79.4	79.4	45.4	45.4	49.0	49.0	40.2	40.2	24.9	24.9									
street motorcycles	4.8	3.8	3.1	2.5	2.0	1.6	1.3	1.0	0.8	0.6	0.5	0.4									
<170 cc	2.4	1.9	1.6	1.2	1.0	0.8	0.6	0.5	0.4	0.3	0.3	0.2									
≥170 cc	6.8	5.4	4.4	3.5	2.7	2.2	1.8	1.4	1.1	0.9	0.7	0.6									

are registered.

3.4 DISCUSSION OF RELIABILITY

The automobile use estimates are based on data from emissions tests conducted between 1972 and 1975, on at least 400 cars per AQCR. Vehicles between one and seven years of age are well-represented in the test sample, but older cars are nearly or entirely absent. Therefore, the tabulated estimates of automobile use by age are less accurate for vehicles more than eight years old than for two-to seven-year-old cars. The sample size of 400+ is statistically large enough to characterize each AQCR vehicle population reliably.

The correlation coefficients of the automobile VMT-versus-age regressions were high, almost always above .8. This indicates an unexpected degree of homogeneity within the data and a smaller degree of variation in use than one might anticipate *a priori*. Thus, the regression results represent the actual use of the tested vehicles well. However, the tested vehicles may not comprise a statistically unbiased sample, for several reasons. First, any vehicle used in emission testing must be in safe operating condition, with a completely intact, non-leaking exhaust system. Since the most heavily-used vehicles will tend to have the most-degraded exhaust systems, they may be rejected disproportionately frequently. Second, the emission testing is performed on randomly-selected vehicles whose owners consent to the testing, in exchange for a $50 savings bond. The fixed amount of money may be a stronger incentive to poorer than to wealthier owners. Third, the emission testing may over-represent less-used cars, whose owners are less inconvenienced by using a borrowed car for two to three days. Finally, the odometer reading of an older car may

underestimate its true cumulative mileage.

Given the above sources of bias, any error in the Tables 3.1 through 3.5 will be one of underestimation. It is not possible to estimate the magnitude of this error. However, if such biases do exist, they are expected to be minimal.

Truck and motorcycle use estimates are based on questionnaire surveys; hence they are probably somewhat less reliable than the automotive data. Also, the annual use of trucks and motorcycles tends to be more variable than that of automobiles, due to the wider variety of use and ownership (commercial, sports, etc.).

We have assumed that the data collected represent vehicle use in 1975. However, it should be noted that the Census Bureau truck survey was conducted in 1972, the motorcycle survey in 1974, and the emission surveillance testing between 1970 and 1976.

3.5 REFERENCES

1. These data are available on tape or hard copy from U. S. EPA, Emission Control Technology Division, Characterization and Applications Branch, Ann Arbor, Michigan. The in-use vehicle emissions tests are conducted by several contractors (e.g., Automotive Test Labs., Aurora, Colorado and Olson Laboratories, Inc., Anaheim, California) under EPA contracts.

2. U. S. Bureau of the Census, 1972 Transportation Census; "Survey of Truck Use."

3. California Air Resources Board, Internal working paper by J. Paskind, 1973 and 1975.

4. Winkler, Fred, "Transportation Control Strategy Development for the Metropolitan Los Angeles Region, report prepared by TRW Transportation and Environmental Operations, Redondo Beach, Ca. for U. S. EPA OAQS, December 1972.

5. Bostich, T. A. and H. J. Greenlagh, "Relationships of Passenger Car Age and other Factors to Miles Driven;" U. S. Department of Commerce, Bureau of Public Roads, 1967.

6. Rothhaar, J., and M. Williams, "Regional Air Quality Impact of Motorcycles," U. S. EPA, Emission Control Technology Division; August 1975. based on data from: Motorcycle Industry Council, Inc., "Survey of Motorcycle Ownership, Usage, and Maintenance," January 1975.

4.0 DISTRIBUTION OF VEHICLE POPULATION BY AGE

The R. L. Polk Company tabulates detailed vehicle registration data for use by government and industry [1]. The data are listed by county of registration and by general vehicle type (automobile, light duty trucks, and heavy duty trucks). In the present study, the total registration count for each AQCR was computed by adding those of all of its counties, as listed in the 1973 Polk national vehicle registration data tape [1]. Tables 4.1 through 4.5 present estimates of the distribution of vehicle population by age, for the five AQCR's, while Tables 4.6 through 4.9 apply to the four metropolitan zones (Phoenix excluded). Two factors should be noted: (1) the estimates do not decrease monotonically, but rather vary according to economic conditions in a given year, and (2) the trends may differ between passenger cars and trucks. The Polk truck registration lists are not categorized by fuel (gasoline versus diesel), and trucks over 9 years old are not grouped by weight (light-duty versus heavy-duty). The table entries for the older light-duty and heavy-duty trucks therefore were computed from a time-series linear regression of the ratio of heavy-to-light trucks, one to eight years old, and from the corresponding "all truck" entries.

In the case of light-duty trucks, the nondivision of data into gasoline and diesel categories is not a problem, due to the very low numbers of light-duty diesel trucks registered during the early 1970's. The age distributions of heavy-duty gasoline and heavy-duty diesel trucks were determined from those of the San Diego AQCR [2], because of the comparability of the winter climates and population densities of the San Diego, Los Angeles, Phoenix, and Houston AQCR's.

Table 4.1

Fraction of Registered Vehicles by Age*
Chicago AQCR

	vehicle age (years)															
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	>15
Passenger Cars	.1086	.1367	.1160	.1053	.1043	.0932	.0802	.0770	.0675	.0436	.0295	.0179	.0070	.0048	.0019	.0010	.0056
Light Duty Trucks**	.1060	.1325	.1003	.0858	.0990	.0701	.0668	.0641	.0550	.0360	.0429	.0320	.0218	.0206	.0154	.0089	.0427
Heavy Duty Trucks**	.0674	.0917	.0837	.0857	.1006	.0883	.0878	.0779	.0665	.0445	.0429	.0333	.0236	.0232	.0180	.0108	.0542
All Trucks	.1002	.1271	.1000	.0891	.1033	.0776	.0749	.0702	.0601	.0396	.0335	.0250	.0170	.0161	.0120	.0070	.0474
Motorcycles*** (Street)																	
•2 Stroke <170cc	.058	.237	.212	.123	.114	.074	.048	.037	.035	.035	.012	—	—	—	—	—	—
•2 Stroke >170cc	.123	.218	.244	.155	.081	.062	.047	.025	.023	.007	.006	.003	—	—	—	—	—
•4 Stroke <170cc	.083	.164	.131	.157	.138	.069	.057	.061	.050	.046	.015	.011	—	—	—	—	—
•4 Stroke >170cc	.126	.243	.192	.157	.086	.052	.039	.029	.024	.021	.005	.009	—	—	—	—	—

*Data are from POLK vehicle registration data tape for 1973.
**The POLK tape lists separate registration counts for light and heavy trucks up to 9 years of age. For older trucks, total registration data were apportioned into light and heavy categories, according to the relative light and heavy populations of 0-to-9-year old trucks.
***Motorcycle data are national statistics from: "Regional Air Quality Impact of Motorcycles," U.S. EPA, August 1975, Appendix I.

Table 4.2

Fraction of Registered Vehicles by Age*
Denver AQCR

	vehicle age (years)																
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	>15
Passenger Cars	.0733	.1149	.1034	.0901	.0940	.0856	.0750	.0776	.0709	.0585	.0472	.0357	.0202	.0262	.0098	.0051	.0308
Light Duty Trucks**	.0820	.1288	.0860	.0782	.0803	.0584	.0512	.0500	.0431	.0405	.0463	.0410	.0302	.0311	.0277	.0175	.1077
Heavy Duty Trucks**	.0753	.1327	.0823	.0621	.0673	.0519	.0544	.0560	.0509	.0550	.0432	.0392	.0296	.0313	.0285	.0185	.1217
All Trucks	.0839	.1349	.0887	.0779	.0808	.0594	.0540	.0534	.0466	.0453	.0382	.0338	.0249	.0256	.0228	.0145	.1152
Motorcycles*** (Street)																	
-2 Stroke <170cc	.058	.237	.212	.123	.114	.074	.048	.037	.035	.035	.012	—	—	—	—	—	—
-2 Stroke >170cc	.123	.218	.244	.155	.081	.062	.047	.025	.023	.007	.006	.003	—	—	—	—	—
-4 Stroke <170cc	.083	.164	.131	.157	.138	.069	.057	.061	.050	.046	.015	.011	—	—	—	—	—
-4 Stroke >170cc	.126	.243	.192	.157	.086	.052	.039	.029	.024	.021	.005	.009	—	—	—	—	—

*Data are from POLK vehicle registration data tape for 1973.
**The division of registration data for light and heavy duty trucks greater than 9 years old is estimated from "all trucks" data.
***Motorcycle data are national figures from: "Regional Air Quality Impact of Motorcycles."

Table 4.3

Fraction of Registered Vehicles by Age*

Houston AQCR

	vehicle age (years)																
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	>15
Passenger Cars	.1088	.1291	.1093	.1041	.1000	.0938	.0768	.0723	.0639	.0463	.0341	.0223	.0105	.0077	.0041	.0021	.0149
Light Duty Trucks**	.1171	.1319	.0994	.0928	.0954	.0796	.0675	.0629	.0545	.0414	.0341	.0266	.0151	.0140	.0121	.0074	.0484
Heavy Duty Trucks**	.1050	.1221	.1008	.1005	.1066	.0792	.0687	.0665	.0558	.0411	.0319	.0250	.0143	.0134	.0116	.0071	.0502
All Trucks	.1171	.1324	.1007	.0948	.0978	.0805	.0684	.0640	.0553	.0419	.0306	.0239	.0136	.0126	.0109	.0066	.0491
Motorcycles*** (Street)																	
•2 Stroke <170cc	.042	.150	.170	.130	.150	.120	.080	.050	.040	.030	.020	.010	-	-	-	-	-
•2 Stroke >170cc	.090	.140	.200	.170	.110	.100	.080	.030	.030	.020	.010	.010	-	-	-	-	-
•4 Stroke <170cc	.060	.100	.100	.170	.190	.110	.090	.070	.040	.040	.010	.010	-	-	-	-	-
•4 Stroke >170cc	.090	.150	.150	.170	.120	.080	.080	.050	.030	.030	.020	.010	-	-	-	-	-

*Data are from POLK vehicle registration data tape for 1973.

**The division of registration data for light and heavy duty trucks greater than 9 years old is estimated from "all trucks" data.

***Motorcycle data are Phoenix AQCR figures from: "Regional Air Quality Impact of Motorcycles," U.S. EPA, August 1975, Appendix I.

Table 4.4

Fraction of Registered Vehicles by Age*
Los Angeles AQCR

	vehicle age (years)																
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	>15
Passenger Cars	.0809	.1012	.0869	.0880	.0958	.0835	.0724	.0755	.0748	.0609	.0473	.0361	.0219	.0192	.0131	.0068	.0357
Light Duty Trucks**	.0839	.1341	.0861	.0822	.0799	.0577	.0477	.0504	.0546	.0491	.0454	.0374	.0257	.0286	.0251	.0155	.0966
Heavy Duty Trucks**	.0482	.0785	.0630	.0824	.0781	.0621	.0496	.0681	.0583	.0605	.0546	.0473	.0341	.0397	.0365	.0235	.1155
All Trucks	.0822	.1315	.0858	.0843	.0818	.0596	.0491	.0536	.0564	.0516	.0416	.0343	.0235	.0262	.0231	.0142	.1011
Motorcycles*** (Street)																	
•2 Stroke <170cc	.042	.150	.170	.130	.150	.120	.080	.050	.040	.030	.020	.010	-	-	-	-	-
•2 Stroke >170cc	.090	.140	.200	.170	.110	.100	.080	.030	.030	.020	.010	.010	-	-	-	-	-
•4 Stroke <170cc	.060	.100	.100	.170	.190	.110	.090	.070	.040	.040	.010	.010	-	-	-	-	-
•4 Stroke >170cc	.090	.150	.150	.170	.120	.080	.080	.050	.030	.030	.020	.010	-	-	-	-	-

*Data are from POLK vehicle registration data tape for 1973.
**The division of registration data for light and heavy duty trucks greater than 9 years old is estimated from "all trucks" data.
***Motorcycle data are Phoenix AQCR figures from: "Regional Air Quality Impact of Motorcycles."

Table 4.5

Fraction of Registered Vehicles by Age*
Phoenix AQCR

	vehicle age (years)															
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	>15
Passenger Cars	.0750	.1050	.0867	.0902	.0962	.0839	.0761	.0784	.0743	.0600	.0491	.0355	.0209	.0179	.0112	.0060	.0337
Light Duty Trucks**	.0886	.1238	.0806	.0813	.0792	.0587	.0546	.0549	.0494	.0460	.0435	.0345	.0262	.0299	.0256	.0158	.0173
Heavy Duty Trucks**	.0717	.1022	.0755	.0787	.0793	.0526	.0526	.0571	.0572	.0552	.0466	.0381	.0297	.0349	.0306	.0194	.1171
All Trucks	.0887	.1241	.0815	.0825	.0805	.0591	.0557	.0560	.0506	.0475	.0406	.0322	.0245	.0280	.0239	.0147	.1099
Motorcycles*** (Street)																	
•2 Stroke <170cc	.042	.150	.170	.130	.150	.120	.080	.050	.040	.030	.020	.010	-	-	-	-	-
•2 Stroke >170cc	.090	.140	.200	.170	.110	.100	.080	.030	.030	.020	.010	.010	-	-	-	-	-
•4 Stroke <170cc	.060	.100	.100	.170	.190	.110	.090	.070	.040	.040	.010	.010	-	-	-	-	-
•4 Stroke >170cc	.090	.150	.150	.170	.120	.080	.080	.050	.030	.030	.020	.010	-	-	-	-	-

*Data are from POLK vehicle registration data tape for 1973.
**The division of registration data for light and heavy duty trucks greater than 9 years old is estimated from "all trucks" data.
***Motorcycle data are Phoenix AQCR figures from: "Regional Air Quality Impact of Motorcycles."

Table 4.6

Fraction of Registered Vehicles by Age*
Chicago Metro Zone

	vehicle age (years)																
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	>15
Passenger Cars	.1123	.1386	.1172	.1045	.1039	.0923	.0802	.0768	.0671	.0430	.0285	.0172	.0066	.0045	.0017	.0009	.0048
Light Duty Trucks**	.1068	.1314	.1023	.0843	.1015	.0690	.0667	.0639	.0559	.0344	.0460	.0341	.0237	.0212	.0160	.0094	.0335
Heavy Duty Trucks**	.0725	.0920	.0856	.0888	.1072	.0914	.0918	.0776	.0657	.0422	.0409	.0315	.0227	.0209	.0164	.0100	.0428
All Trucks	.1006	.1246	.1016	.0897	.1081	.0796	.0780	.0713	.0617	.0386	.0331	.0245	.0170	.0152	.0115	.0068	.0381
Motorcycles*** (Street)																	
•2 Stroke <170cc	.058	.237	.212	.123	.114	.074	.048	.037	.035	.035	.012	-	-	-	-	-	-
•2 Stroke >170cc	.123	.218	.244	.155	.081	.062	.047	.025	.023	.007	.006	.003	-	-	-	-	-
•4 Stroke <170cc	.083	.164	.131	.157	.138	.069	.057	.061	.050	.046	.015	.011	-	-	-	-	-
•4 Stroke >170cc	.126	.243	.192	.157	.086	.052	.039	.029	.024	.021	.005	.009	-	-	-	-	-

*Data are from POLK vehicle registration data tape for 1973.
**The division of registration data for light and heavy duty trucks greater than 9 years old is estimated from "all trucks" data.
***Motorcycle data are national figures from: "Regional Air Quality Impact of Motorcycles."

Table 4.7

Fraction of Registered Vehicles by Age*

Denver Metro

	vehicle age (years)																
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	>15
Passenger Cars	.0788	.1135	.1083	.0884	.0917	.0838	.0738	.0766	.0713	.0593	.0480	.0368	.0210	.0169	.0100	.0052	.0317
Light Duty Trucks**	.0769	.1227	.0821	.0771	.0820	.0603	.0499	.0490	.0408	.0376	.0548	.0478	.0345	.0361	.0310	.0202	.0972
Heavy Duty Trucks**	.0746	.1372	.0843	.0662	.0683	.0499	.0565	.0561	.0508	.0565	.0434	.0386	.0285	.0305	.0266	.0177	.1144
All Trucks	.0810	.1357	.0882	.0783	.0826	.0605	.0554	.0547	.0469	.0466	.0393	.0342	.0247	.259	.0222	.0145	.1095
Motorcycles*** (Street)																	
•2 Stroke <170cc	.058	.237	.212	.123	.114	.074	.048	.037	.035	.035	.012	-	-	-	-	-	-
•2 Stroke >170cc	.123	.218	.244	.155	.081	.062	.047	.025	.023	.007	.006	.003	-	-	-	-	-
•4 Stroke <170cc	.083	.164	.131	.157	.138	.069	.057	.061	.050	.046	.015	.011	-	-	-	-	-
•4 Stroke >170cc	.126	.243	.192	.157	.086	.052	.039	.029	.024	.021	.005	.009	-	-	-	-	-

*Data are from POLK vehicle registration data tape for 1973.

**The division of registration data for light and heavy duty trucks greater than 9 years old is estimated from "all trucks" data.

***Motorcycle data are national figures from: "Regional Air Quality Impact of Motorcycles."

Table 4.8

Fraction of Registered Vehicles by Age*
Houston Metro Zone

	vehicle age (years)															
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	>15
Passenger Cars	.1135	.1322	.1117	.1044	.1002	.0931	.0762	.0709	.0626	.0450	.0347	.0208	.0099	.0072	.0040	.0019	.0136
Light Duty Trucks**	.1234	.1385	.1046	.0945	.0967	.0799	.0668	.0621	.0534	.0399	.0316	.0239	.0137	.0125	.0108	.0065	.0413
Heavy Duty Trucks**	.1200	.1352	.1124	.1115	.1135	.0808	.0678	.0603	.0484	.0328	.0256	.0190	.0107	.0096	.0082	.0048	.0394
All Trucks	.1242	.1393	.1065	.0974	.0996	.0807	.0675	.0624	.0533	.0394	.0281	.0213	.0122	.0112	.0096	.0058	.0414
Motorcycles*** (Street)																	
•2 Stroke <170cc	.042	.150	.170	.130	.150	.120	.080	.050	.040	.030	.020	.010	-	-	-	-	-
•2 Stroke >170cc	.090	.140	.200	.170	.110	.100	.080	.030	.030	.020	.010	.010	-	-	-	-	-
•4 Stroke <170cc	.060	.100	.100	.170	.190	.110	.090	.070	.040	.040	.010	.010	-	-	-	-	-
•4 Stroke >170cc	.090	.150	.150	.170	.120	.080	.080	.050	.030	.030	.020	.010	-	-	-	-	-

*Data are from POLK vehicle registration data tape for 1973.
**The division of registration data for light and heavy duty trucks greater than 9 years old is estimated from "all trucks" data.
***Motorcycle data are from: "Regional Air Quality Impact of Motorcycles", U.S.E.P.A., August 1975, Appendix I, Figures are for Phoenix-Tucson AQCR.

Table 4.9

Fraction of Registered Vehicles by Age*

Los Angeles Metro Zone

	vehicle age (years)																
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	>15
Passenger Cars	.0826	.1000	.0847	.0871	.0946	.0830	.0723	.0758	.0756	.0616	.0480	.0366	.0224	.0194	.0131	.0068	.0362
Light Duty Trucks**	.0809	.1284	.0850	.0819	.0807	.0586	.0488	.0515	.0554	.0498	.0466	.0386	.0266	.299	.0263	.0158	.0954
Heavy Duty Trucks**	.0499	.0797	.0663	.0877	.0809	.0659	.0493	.0673	.0573	.0588	.0525	.0454	.0326	.0382	.0349	.0217	.1114
All Trucks	.0792	.1259	.0851	.0850	.0830	.0612	.0502	.0550	.0573	.0524	.0420	.0348	.0240	.0269	.0237	.0142	.1002
Motorcycles*** (Street)																	
•2 Stroke <170cc	.042	.150	.170	.130	.150	.120	.080	.050	.040	.030	.020	.010	-	-	-	-	-
•2 Stroke >170cc	.090	.140	.200	.170	.110	.100	.080	.030	.030	.020	.010	.010	-	-	-	-	-
•4 Stroke <170cc	.060	.100	.100	.170	.190	.110	.090	.070	.040	.040	.010	.010	-	-	-	-	-
•4 Stroke >170cc	.090	.150	.150	.170	.120	.080	.080	.050	.030	.030	.020	.010	-	-	-	-	-

*Data are from POLK vehicle registration data tape for 1973.

**The division of registration data for light and heavy duty trucks greater than 9 years old is estimated from "all trucks" data.

***Motorcycle data are from: "Regional Air Quality Impact of Motorcycles", U.S.E.P.A., August 1975, Appendix I.

The assumption that the San Diego diesel and gasoline truck age distributions also apply to these other areas was tested by performing linear regressions among the light-duty truck distributions of the four areas (San Diego, Los Angeles, Phoenix, and Houston) and among the corresponding heavy-duty truck distributions. The correlation coefficients (R) exceeded .7 for each of the regressions performed. In all regressions, the San Diego data were the independent variable. The strong correlations obtained support the decision to use the San Diego distributions of diesel and gasoline heavy-duty trucks.

Again, motorcycle data were obtained from the EPA's study of the air quality impact of motorcycles [3]. The "warm climate" figures (which actually apply to the Los Angeles AQCR) were used for Phoenix, Houston, and Los Angeles, while the "national averages" statistics were used for Chicago and Denver.

The automobile and total truck data presented in this chapter are accurate, due to the effort expended by most states in keeping track of vehicle registrations. The estimates presented in this chapter apply to vehicle registrations, which should approximate total counts of in-use vehicles as well. The primary reasons for any disparity would be the failure of some motorists to register their vehicles in their home AQCR and the registration of essentially non-used vehicles by collectors. Neither of these factors is expected to be significant, however.

The motorcycle population estimates presented above are less reliable, due to the lower accuracy and availability of applicable data. Accurate motorcycle counts are difficult to obtain, due to state-to-state differences in registration laws and definition problems

(e.g., the distinctions between street and off-road motorcycles or between motorcycles and motorbikes are not always clear).

4.0 REFERENCES

1. R. L. Polk and Company, data tapes of U. S. vehicle registrations by county, general vehicle type, and model year. 1973 tape was used in this study.

2. Sloop, Michael, et al, "Air Pollution Trends in the San Diego Air Basin, San Diego Air Quality Planning Team, San Diego, Ca., October 1975.

3. Rothhaar, J., M. Williams, "Regional Air Quality Impact of Motorcycles," Appendix I; Technical Support Report for Regulatory Action, U. S. EPA, Emission Control Technology Division, August 1975. Based on data from Motorcycle Industries Council.

5.0 VEHICLE MILES TRAVELED IN 1975, BY VEHICLE AGE AND TYPE

By multiplying the number of vehicles of each age and type by the corresponding average VMT per vehicle, one can compute the total VMT by each age and type of vehicle, for each AQCR. Vehicles registered within one AQCR are frequently operated within another. The statistics presented here enumerate total use (in and out of the AQCR) of vehicles registered within a given AQCR, rather than the total use within the AQCR of all vehicles, irrespective of where they are registered. For cars and short-haul vehicles, the two sets of data should be comparable, although they can differ in the case of long-haul heavy-duty trucks, most of whose usage is between AQCR's.

Without detailed data on total vehicle usage within the AQCR, the best estimate of 1975 VMT by vehicle age and type is simply the total use of vehicles registered there. Tables 5.1 through 5.5 list these data, which will tend to overestimate the contribution of heavy-duty trucks to the VMT of each AQCR, but which probably depict auto and LDT use well. The entries in these tables which are derived from the corresponding entries in the tables of Chapters 3 and 4, are based on AQCR-specific and state-specific data - it was not necessary to estimate any of these figures from nationwide data.

Table 5.1. Chicago VMT in 1975 by Vehicle Age*

VEHICLE TYPE	VEHICLE AGE (YEARS) 0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
PASSENGER CARS	.121	.185	.141	.116	.104	.085	.068	.060	.050	.030	.019	.011	.004	.003	.001	.001	.001	.001	.001	.001	.000
LIGHT DUTY TRUCKS	.155	.194	.126	.108	.086	.061	.053	.050	.047	.030	.021	.016	.011	.010	.007	.004	.004	.004	.003	.003	.003
HEAVY DUTY TRUCKS	.128	.174	.123	.126	.103	.090	.070	.062	.038	.026	.012	.010	.007	.007	.005	.003	.003	.003	.002	.002	.001
MOTORCYCLES < 170 cc	.067	.274	.226	.120	.111	.066	.043	.029	.025	.025	.009	.007	0.	0.	0.	0.	0.	0.	0.	0.	0.
MOTORCYCLES ≥ 170 cc	.185	.309	.206	.143	.065	.033	.022	.016	.010	.007	.002	.002	0.	0.	0.	0.	0.	0.	0.	0.	0.

*The table entries are the fractions of total VMT by vehicles of each type, of the ages specified by the column headings. Thus, 12.1% of all passenger car VMT is due to new cars (age 0).

Table 5.2 Denver VMT in 1975 by Vehicle Age*

VEHICLE TYPE	VEHICLE AGE (YEARS) 0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
PASSENGER CARS	.083	.157	.128	.103	.098	.084	.068	.067	.057	.045	.034	.024	.013	.016	.006	.003	.003	.003	.003	.003	.003
LIGHT DUTY TRUCKS	.111	.174	.103	.094	.077	.056	.056	.055	.028	.027	.034	.030	.022	.023	.020	.013	.012	.010	0.	0.	0.
HEAVY DUTY TRUCKS	.128	.225	.150	.114	.070	.054	.048	.049	.028	.030	.014	.013	.010	.010	.009	.006	.005	.004	.004	.004	.003
MOTORCYCLES < 170 cc	.067	.274	.226	.120	.111	.066	.043	.029	.025	.025	.009	.007	0.	0.	0.	0.	0.	0.	0.	0.	0.
MOTORCYCLES ≥ 170 cc	.185	.309	.206	.143	.065	.033	.022	.016	.010	.007	.002	.002	0.	0.	0.	0.	0.	0.	0.	0.	0.

*The table entries are the fractions of total VMT by vehicles of each type, by the ages specified by the column headings. Thus, 8.3% of all passenger car VMT is due to new cars (age 0).

Table 5.3 Houston VMT in 1975 by Vehicle Age*

VEHICLE TYPE	VEHICLE AGE (YEARS)																				
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
PASSENGER CARS	.152	.186	.133	.112	.096	.082	.062	.053	.047	.029	.020	.013	.006	.004	.002	.001	.001	.001	.001	.001	.001
LIGHT DUTY TRUCKS	.158	.178	.111	.103	.094	.078	.059	.055	.037	.028	.021	.017	.009	.009	.008	.005	.005	.004	.003	.003	.003
HEAVY DUTY TRUCKS	.146	.170	.145	.144	.106	.078	.057	.055	.028	.020	.011	.008	.005	.004	.004	.002	.002	.002	.002	.002	.002
MOTORCYCLES < 170 cc	.087	.244	.233	.134	.129	.082	.041	.021	.014	.008	.005	.002	0.	0.	0.	0.	0.	0.	0.	0.	0.
MOTORCYCLES ≥ 170 cc	.176	.233	.190	.171	.093	.051	.041	.020	.010	.008	.004	.002	0.	0.	0.	0.	0.	0.	0.	0.	0.

*The table entries are the fractions of total VMT by vehicles of each type, by the ages specified by the column headings. Thus, 15.2% of all passenger car VMT is due to new cars (age 0).

Figure 6.4 Los Angeles VMT in 1975 by Vehicle Age*

VEHICLE TYPE	VEHICLE AGE (YEARS) 0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
PASSENGER CARS	.135	.185	.130	.109	.101	.076	.058	.053	.047	.034	.024	.016	.009	.007	.004	.002	.002	.002	.002	.002	.001
LIGHT DUTY TRUCKS	.133	.212	.113	.075	.054	.042	.044	.073	.066	.031	.026	.018	.020	.017	.011	.009	.007	.005	.005	.005	.003
HEAVY DUTY TRUCKS	.080	.130	.095	.124	.100	.064	.065	.061	.064	.034	.029	.021	.025	.023	.015	.010	.010	.008	.008	.008	.006
MOTORCYCLES < 170 cc	.087	.244	.233	.134	.129	.082	.041	.021	.014	.008	.005	.002	0.	0.	0.	0.	0.	0.	0.	0.	0.
MOTORCYCLES ≥ 170 cc	.176	.233	.190	.171	.093	.051	.041	.020	.010	.008	.004	.002	0.	0.	0.	0.	0.	0.	0.	0.	0.

*The table entries are the fractions of total VMT by vehicles of each type, by the ages specified by the column headings. Thus, 13.5% of all passenger car VMT is due to new cars (age 0).

Table 5.5 Phoenix VMT in 1975 by Vehicle Age*

VEHICLE TYPE	VEHICLE AGE (YEARS) 0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
PASSENGER CARS	.103	.135	.100	.097	.098	.081	.071	.070	.064	.050	.039	.028	.016	.013	.008	.004	.005	.005	.005	.005	.004
LIGHT DUTY TRUCKS	.137	.192	.105	.106	.074	.055	.055	.055	.055	.051	.026	.021	.016	.018	.015	.009	.005	.003	.001	.001	.000
HEAVY DUTY TRUCKS	.129	.224	.108	.112	.065	.043	.046	.050	.041	.040	.021	.017	.013	.016	.014	.009	.007	.005	.005	.005	.003
MOTORCYCLES < 170 cc	.087	.244	.233	.134	.129	.082	.041	.021	.014	.008	.005	.002	0.	0.	0.	0.	0.	0.	0.	0.	0.
MOTORCYCLES ≥ 170 cc	.176	.233	.190	.171	.093	.051	.041	.020	.010	.008	.004	.002	0.	0.	0.	0.	0.	0.	0.	0.	0.

*The table entries are the fractions of total VMT by vehicles of each type, by the ages specified by the column headings. Thus, 10.3% of all passenger car VMT is due to new cars (age 0).

6.0 VEHICLE MILE GROWTH RATE

To predict future air quality of an AQCR, one must know the current and predicted VMT trends in it. Local governmental planning agencies, e.g., Los Angeles Regional Transportation Study, Chicago Area Transportation Study, etc. are primary sources of data of this type. Since detailed data are not available from local agencies, the transportation projections for Chicago, Denver, Houston, and Phoenix were taken from the EPA's "Regional Air Quality Impact of Motorcycles" [1]. The authors of Reference 1 did not specifically state the basis for their VMT growth rate estimates for Chicago, Denver, and Houston; for Phoenix, they obtained the 'other vehicles' VMT growth rate directly from Reference 3. San Diego VMT projections by vehicle type [2] were used in place of Los Angeles data. TSC considered References 1-3 to be the best available at the time.

Tables 6.1 through 6.5 present the future VMT projections for the five AQCR's for the years 1975 through 1990.

Table 6.1 Vehicle Mile Growth Rates* 1975-90, Chicago (%)

VEHICLE TYPE	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1990
Passenger Cars	100	103	106	109	112	115	117	119	121	123	125	137
Trucks	100	103	106	109	112	115	117	119	121	123	125	137
Motorcycles	100	104	108	112	116	121	126	131	136	141	147	162

*Based on annual growth rates of: [1]

Motorcycles 4% 1975-1985
2% after 1985

Other vehicles 3% 1975-1980
2% after 1980

Table 6.2 Vehicle Mile Growth Rates* 1975-90, Denver (%)

VEHICLE TYPE	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1990
Passenger Cars	100	103	106	109	112	115	117	119	121	123	125	137
Trucks	100	103	106	109	112	115	117	119	121	123	125	137
Motorcycles	100	104	108	112	116	121	126	131	136	141	147	162

*Based on annual growth rates of: [1] Motorcycles 4% 1975-1985
2% thereafter

Other vehicles 3% 1975-1980
2% after 1985

Table 6.3 Vehicle Mile Growth Rates*1975-90, Houston (%)

VEHICLE TYPE	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1990
Passenger Cars	100	105	110	116	122	128	131	134	137	140	143	157
Trucks	100	105	110	116	122	128	131	134	137	140	143	157
Motorcycles	100	108	117	126	136	147	159	172	186	201	217	260

*Based on annual growth rates of: [1]Motorcycles 8% until 1985
4% 1986-1992
2% thereafter

Other vehicles 5% 1975-1980
2% thereafter

Table 6.4 Vehicle Mile Growth Rates 1975-1990, Los Angeles AQCR
Percent of 1975 Total VMT

VEHICLE TYPE	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1990
Passenger Cars	100	103	106	109	112	115	119	123	127	131	135	150
Light Duty Truck*	100	103	108	108	111	114	119	124	130	135	140	158
Heavy Duty Trucks	100	104	108	112	116	120	127	134	142	149	156	187
Gasoline	100	103	107	110	114	117	124	131	138	145	152	180
Diesel	100	105	109	114	118	123	130	137	145	152	159	193
Motorcycles	100	105	109	114	118	123	129	135	140	146	152	176

*This is all light duty trucks, which are almost all gasoline. Since diesel LDT population in early 1970's was insignificant, diesel LDT population forecasts are difficult.

Annual vehicle mile growth rates are: [2] Passenger Cars 3%
Light Duty Truck 3%
Heavy Duty Trucks 3%
Heavy Duty Diesel 5%
Motorcycles 5%

Table 6.5 Vehicle Mile Growth Rates 1975-90, Phoenix AQCR (%)

VEHICLE TYPE	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1990
Passenger Cars	100	105	110	116	122	128	132	136	140	144	148	170
Trucks	100	105	110	116	122	128	132	136	140	144	148	170
Motorcycles	100	108	117	126	131	136	141	147	153	159	165	197

Based on annual growth rates of: [3, as cited in 1]

Motorcycles 8% 1975-1978
4% 1979-1989
2% 1989-

Other vehicles 5% 1975-1980
3% 1981-

6.1 REFERENCES

1. Rothhaar, J., M. Williams, "Regional Air Quality Impact of Motorcycles, Appendix 1," Technical Support Report by Emission Control Technology Division of Office of Mobile Source Air Pollution Control, August 1975.

2. Sloop, Michael, et al, "Air Pollution Trends in The San Diego Air Basin," San Diego Air Quality Planning Team, October 1975.

3. "Transportation Control Strategy for the Phoenix-Tuscon AQ Area" APTD 1369, February 1973.

7.0 VEHICLE SALES GROWTH RATES

Older motor vehicles (with high emission rates) are gradually being replaced by new, low-emission vehicles. As this occurs the average in-use vehicle emissions will decrease. The rate of emission abatement corresponding to any set of proposed future emission standards will depend not only on the standards themselves but also on:

1) the rate at which new vehicles replace older ones in the in-use vehicle population;
2) the vehicle population growth rate (new vehicle sales minus scrappage rate); and
3) the distribution of vehicle miles traveled by vehicle age.

The objective of the present chapter is to predict new vehicle sales by vehicle type and Air Quality Control Region, for the years 1975 through 1990.

7.1 DATA SOURCES

Although new vehicle sales forecasts by AQCR or city are generally not available, national new vehicle sales projections, which constitute an important economic indicator, can be obtained from several economic forecast publications, such as the "UCLA National Business Forecast" [1]. This publication lists total new automobile sales for the years 1961 through 1975 and projected sales for 1976 through 1990. Since only national automobile sales figures are given, car and truck sales projections for individual AQCR's must be estimated, as explained in the following section.

Historical state-by-state new car and truck registration figures are available in "Automotive News" [2], "Motor Vehicle Facts and Figures" [3], and "Motor Truck Facts" [4]. To use these data in this

task, one must assume that new vehicle registrations equal new vehicle sales. This assumption is good, as long as each new vehicle is registered in the AQCR of purchase. Due to differences in registration fees and sales tax, it can be advantageous to purchase a new vehicle in a state other than one's own. However, to discourage this practice, many states collect a late sales tax (Use Tax) on vehicles recently purchased elsewhere. Because of the existance of Use Taxes, it is reasonable to assume that each vehicle is purchased in the AQCR in which it will be registered. Since the vehicle sales data base comprises only historical state-by-state registration figures and national vehicle sales projections, one must estimate future AQCR-by-AQCR vehicle sales from these and other, less direct, data.

New car registrations are listed by state and it is possible to estimate the apportionment of new car sales by state. To predict future vehicle sales by state, one needs projections of both national new vehicle sales and the apportionment of new vehicle sales among the states. While national sales projections are available, the apportionment of sales among the states must be estimated from other data, primarily the Census Bureau's population growth projection, which is subdivided by Standard Metropolitan Statistical Area (SMSA) [5,6]. The bureau lists 1970 census data and projections for the years 1971, 1974, 1975, 1980, and 1990. Since population growth rates differ from one AQCR to the next, future vehicle sales growth rates probably also will differ. In the absence of region-specific vehicle projections, the best way to estimate these is from projections of national sales and regional populations, discussed below.

7.2 PROCEDURE AND RESULTS

New vehicle registrations are assumed to equal new vehicle sales within each AQCR. Second, new vehicle sales per capita are assumed to be uniform within each state, so that the fraction of statewide new vehicle sales attributable to a given AQCR equals the fraction of state population residing within that AQCR. Third, per capita new vehicle sales within each AQCR are assumed to change over time by the same percentage as the corresponding national figures. Thus, the vehicle sales projections presented here are based on national sales projections, historical state registrations, and national and regional population projections. Although these new vehicle projections do not explicitly reflect economic trends in the individual AQCR's, they can be modified to do so.

To develop regional vehicle sales projections, one must first compute the present and projected population of each AQCR of interest, by adding the corresponding figures for the individual SMSA's or counties it comprises.

New vehicle sales were projected only for AQCR's, rather than for both metropolitan zones and AQCR's, for two reasons. First, the Census Bureau's population projections are itemized by SMSA, rather than by the metropolitan zones within the SMSA's. Since population projections for individual metropolitan zones must be obtained from state and local planning agencies (e.g., the Southern California Association of Governments), they are not available for all metropolitan zones of interest and may not be directly comparable to one another. Second, because of the high concentration of commercial activity within metropolitan zones, per capita vehicle sales within each will exceed the corresponding statewide average, i.e., many vehicles sold in a

particular metropolitan center may be registered in a nearby suburban county or city. Therefore, one cannot assume that all vehicles are registered in the metropolitan zone of purchase.

Given the present and projected population of each AQCR and of the nation, the next step is to compute the fraction of statewide new vehicle sales attributable to each AQCR. This fraction is assumed to be the ratio of the AQCR population to that of the state containing it. AQCR new vehicle sales are given by the equation:

$$S(a_i,t_j) = \frac{P(a_i,t_j) \cdot S(s_i,t_j)}{P(s_i,t_j)} \qquad (1)$$

where S, the new vehicle sales, and P, the population, are both functions of geographic area and time. In this notation, the ith AQCR, which is labeled "a_i" , lies in the state "s_i" . The variable "t" refers to the year to which a given projection applies; thus, $P(a_i,t_j)$ is the population of the ith AQCR in the jth year. The base year 1975, will be denoted "t_0".

State-by-state new vehicle sales (registrations) are given only for the base year and future AQCR sales cannot be estimated using equation (1). However, one can forecast future AQCR sales from the national sales projections, $S(n,t_j)$ and from AQCR and national population forecast, $P(a_i,t_j)$ and $P(n,t_j)$.

To complete the AQCR sales forecasts, it was assumed that per capita new vehicle sales for each AQCR will change in proportion to trends in the national figure. Thus, if national sales per capita are projected to increase 10% over a 10-year period, then per capita sales

in each AQCR are also assumed to increase by 10% during that time. National per capita sales are total national sales divided by total national population, the ratio of future to base year national per capita new vehicle sales is:

$$\frac{S(n,t_j)}{P(n,t_j)} \div \frac{S(n,t_o)}{P(n,t_o)} = \frac{S(n,t_j) \cdot P(n,t_o)}{S(n,t_o) \cdot P(n,t_j)} \qquad (2)$$

The base year (t_o) sales in the ith AQCR, from equation (1), are:

$$S(a_i,t_o) = \frac{P(a_i,t_o) \cdot S(s_i,t_o)}{P(s_i,t_o)} \qquad (3)$$

If AQCR population were to remain constant, then sales would increase in proportion to the growth in national per capita sales, viz:

$$\begin{aligned} \dot{S}(a_i,t_j) &= S(a_i,t_o) \cdot \frac{S(n,t_j) \cdot P(n,t_o)}{P(n,t_j) \cdot S(n,t_o)} \\ &= \frac{P(a_i,t_o) \cdot S(s_i,t_o) \cdot S(n,t_j) \cdot P(n,t_o)}{P(s_i,t_o) \cdot P(n,t_j) \cdot S(n,t_o)} \end{aligned} \qquad (4)$$

where $\dot{S}(a_i, t_j)$ is the constant-population projection of sales for the ith AQCR in the jth year.

Finally, one must allow for changes in the population of the AQCR.

Since $S'(a_i,t_j)$ was developed under the assumption of zero population growth in the AQCR, it will underestimate future sales in growing AQCR's and overestimate sales in declining regions. Allowing for future population changes, the sales projections become:

$$S(a_i,t_j) = S'(a_i,t_j) \cdot \frac{P(a_i,t_j)}{P(a_i,t_o)}$$

$$= \frac{P(a_i,t_j) \cdot S(n,t_o) \cdot S(n,t_j)\, P(n,t_o)}{P(s_i,t_o) \cdot P(n,t_j) \cdot S(n,t_o)} \qquad (5)$$

One can verify equation (5) by noting that jth year per capita sales within the ith AQCR are given by:

$$\frac{S(a_i,t_j)}{P(a_i,t_j)} = \frac{S(s_i,t_j) \cdot S(n,t_j) \cdot P(n,t_o)}{P(s_i,t_o) \cdot P(n,t_j) \cdot S(n,t_o)} \qquad (6)$$

which is simply the statewide base year (t_o) per capita sales multiplied by the relative change in the national per capita sales from t_o to t_j.

While equation (5) can be used to predict future car sales, it cannot be used directly for truck sales, due to incomplete data. New truck registrations by state are available for the years 1967 through 1975 [8], but future sales projections are not. AQCR-specific future truck sales were predicted from the car sales projections using the historical trends in the ratio of truck to car sales. Separate

registration trends for new light duty diesel trucks (LDD), light duty gasoline trucks (LDG), and heavy duty diesel trucks (HDD), heavy duty gasoline trucks (HDG) were calculated from state-by-state registration data which are categorized by truck type. A simple linear regression of the year-by-year truck/car sales ratio for each truck type and for each AQCR was used to predict future trends in truck sales. The slopes of the regression equations were divided by two, because the years 1967 through 1975, on which the truck/car sales ratio regressions were performed, represent a period of unusually rapidly expanding truck sales. For example, since the ratio of LDG truck to car sales in Arizona increased 10% per year between 1967 and 1975, our 1975 to 1990 projections assume that the ratio of truck to car sales in the Phoenix AQCR will grow at 5% per year.

Tables 7.1 through 7.5 project future vehicle sales, by vehicle type and AQCR. The figures represent each year's projected sales as a percentage of 1975 sales.

7.3 LIMITATIONS OF THE ANALYSIS

The accuracy of the estimates of future vehicle sales is related to the accuracy of the population and sales projections. Future changes in population, economics, government regulations, and energy supply will have radical impacts on vehicle sales.

The truck sales projections were derived from the auto sales forecasts and the regression of the truck /car sales ratios against time. Since the regression equations fit the historical truck/car sales ratio well, (R^2 exceeds .8 for every AQCR), the truck sales projections should be accurate.

The assumption that the car/truck sales ratio will continue to

TABLE 7.1 PROJECTED VEHICLE SALES GROWTH ROUTES, 1975-1990 (PERCENT OF 1975 SALES)

Chicago AQCR

	1975	1976	1977	1978	1978	1980	1981	1982	1983	1984	1985	1990
Automobiles	100	117	131	132	140	132	142	146	143	146	148	149
Trucks*												
All	100	119	137	142	154	150	166	174	175	184	190	214
Light-duty gasoline	100	120	138	145	157	154	171	181	182	193	200	225
heavy-duty gasoline	100	113	124	121	123	112	116	114	105	101	95	104
heavy-duty diesel	100	120	140	147	160	157	175	186	189	200	209	160
Motorcycles												

*Light-duty diesel truck sales not projected, due to small 1970-1975 sample size.

TABLE 7.2 PROJECTED VEHICLE SALES GROWTH RATES, 1975-1990 (PERCENT OF 1975 SALES)

Denver AQCR

	1975	1976	1977	1978	1978	1980	1981	1982	1983	1984	1985	1990
Automobiles	100	117	132	133	140	133	144	149	146	151	154	158
Trucks												
All	100	124	134	148	160	156	172	183	183	194	202	228
Light-duty gasoline	100	125	156	151	164	180	178	191	191	203	211	240
heavy-duty gasoline	100	118	138	126	129	120	121	119	110	107	105	120
heavy-duty diesel	100	125	157	153	167	164	183	196	198	211	222	251
Motorcycles												

*Light-duty diesel truck sales not projected, due to small 1970-1975 sample size.

TABLE 7.3 PROJECTED VEHICLE SALES GROWTH RATES, 1975-1990 (PERCENT OF 1975 SALES)

Houston AQCR

	1975	1976	1977	1978	1978	1980	1981	1982	1983	1984	1985	1990
Automobiles	100	116	129	129	134	126	137	143	140	145	149	156
Trucks												
All	100	117	132	134	142	135	149	158	157	164	172	192
Light-duty gasoline	100	118	134	138	144	139	154	164	163	173	180	201
heavy-duty gasoline	100	111	119	114	113	101	105	103	94	90	86	96
heavy-duty diesel	100	118	135	138	147	143	158	168	170	180	188	211
Motorcycles												

*Light-duty diesel truck sales not projected, due to small 1970-1975 sample size.

TABLE 7.4 PROJECTED VEHICLE SALES GROWTH RATES, 1975-1990 (PERCENT OF 1975 SALES)

Los Angeles AQCR

	1975	1976	1977	1978	1978	1980	1981	1982	1983	1984	1985	1990
Automobiles	100	117	131	132	139	131	141	146	142	146	149	151
Trucks												
All	100	122	141	146	158	152	168	178	177	186	194	218
Light-duty gasoline	100	123	143	148	163	156	173	184	197	195	203	228
heavy-duty gasoline	100	117	110	124	126	114	117	116	106	102	97	109
heavy-duty diesel	100	123	144	150	164	160	178	190	200	202	213	239
Motorcycles												

*Light-duty diesel truck sales not projected, due to small 1970-1975 sample size.

TABLE 7.5 PROJECTED VEHICLE SALES GROWTH RATES, 1975-1990 (PERCENT OF 1975 SALES)

Phoenix AQCR

	1975	1976	1977	1978	1978	1980	1981	1982	1983	1984	1985	1990
Automobiles	100	116	129	129	135	127	139	146	144	150	155	166
Trucks												
All	100	121	140	143	153	147	164	176	177	188	198	231
Light-duty gasoline	100	122	142	146	156	151	169	179	180	196	206	254
heavy-duty gasoline	100	115	126	121	123	110	115	114	106	104	99	115
heavy-duty diesel	100	122	143	148	159	154	171	188	191	205	217	254
Motorcycles												

*Light-duty diesel truck sales not projected, due to small 1970-1975 sample size.

grow at 50% of its recent historical rate is reasonable. The early 1970's growth rate of truck sales cannot be maintained indefinitely, due to gradual saturation of the market. However, the smaller light-duty trucks, particularly pickups and vans, will probably continue to be popular as general purpose, personal transportation vehicles, displacing cars in many instances.

The vehicle sales projections presented in this chapter can be modified as newer data become available.

7.5 REFERENCES

1. Management Research Associates of the University of California, The UCLA National Business Forecast, "Long-Term Forecast, 1977-1990"; subscription report series published by General Electric Company, MAP Services.

2. "1977 Market Data Book" issue of Automotive News; Motor Vehicle Manufacturers Association (MVMA), 1977.

3. "MVMA Motor Vehicle Facts and Figures, 1977"; published yearly by MVMA.

4. MVMA, "1975 Motor Truck Facts"; published by MVMA.

5. Social and Economic Statistics Administration, "Area Economic Projections 1990"; U. S. Department of Commerce, 1974(?); U. S. Government Printing Office, No. 003-024-00490-9.

6. Bureau of the Census; "Estimates of the Population of Counties and Metropolitan Areas: July 1, 1974 and 1975;" U. S. Department of Commerce, September 1977 (Series P-25, NO. 709).

8.0 MONTHLY TEMPERATURES: RANGE AND AVERAGE

Monthly mean temperature data for carefully selected stations within the metropolitan zones and AQCR's of interest were extracted from the 1967 through 1975 annual U.S. Climatic Summary [1]. Tables 8.1 through 8.5 list these data for the Chicago, Denver, Houston, Los Angeles, and Phoenix AQCR's, while Tables 8.6 through 8.9 present the same data for the respective metropolitan zones. As in earlier tasks, the Phoenix metropolitan zone was not considered separately from its AQCR.

In performing this task, we assumed that the climate at each metropolitan center of interest was similar to that at the nearest weather station. For example, the temperatures entered in Table 8.6 were recorded not in the Chicago civic center, but at nearby Chicago University. Average temperatures for each AQCR were computed from data for five selected weather stations within its boundaries. To guarantee good coverage of each AQCR, widely spaced weather stations were chosen. In AQCR's containing multiple climatic zones (e.g., Los Angeles, with its shoreline, coastal plain, and inland valleys), we selected at least one weather station per climatic zone, choosing two weather stations for the most populous areas. The mean temperature of the AQCR was then assumed to be the arithmetic mean of the temperatures of the five enclosed weather stations. Occasionally, there was a temporary or permanent closure of weather stations of interest. In most cases of station discontinuation, however, there were adjacent or proximate stations with very similar climate. The footnotes of each table list both the primary station(s) and all substitute stations used in its compilation.

Table 8.1. Monthly Mean* Temperature for Chicago AOCR (^{o}F)

	1967	1968	1969	1970	1971	1972	1973	1974	1975	AVG.**
JAN	27	23	20	15	18	20	28	25	27	22
FEB	20	23	29	24	26	24	29	27	27	25
MAR	37	42	33	33	33	33	44	38	33	36
APR	49	51	49	50	47	44	48	51	43	48
MAY	54	56	59	61	56	60	56	56	62	58
JUN	70	70	64	68	73	65	71	66	70	69
JUL	69	73	73	74	71	72	75	75	74	73
AUG	67	73	74	72	71	72	74	71	74	72
SEP	63	65	65	65	68	64	67	61	60	64
OCT	52	55	52	54	60	50	58	53	56	54
NOV	36	40	37	39	40	38	42	41	46	40
DEC	29	27	27	29	34	25	28	31	31	29

*Monthly values represent averages of the monthly mean temperatures over all five stations.

**1967-1975 9-Year Average

Stations Used:

1) Chicago WB City No. 2 1/67 through 10/70
   Chicago University 11/70 through 12/75.
2) O'Hare Field
3) Waukegan
4) Aurora
5) Park Forest

Table 8.2. Monthly Mean* Temperature for Denver AOCR (^{o}F)

	1967	1968	1969	1970	1971	1972	1973	1974	1975	AVG.**
JAN	34	31	35	31	31	30	25	25	30	30
FEB	35	34	35	39	30	36	33	35	30	34
MAR	43	41	32	34	37	46	37	42	35	39
APR	48	45	51	43	46	49	41	46	41	46
MAY	52	56	58	58	53	57	54	59	50	55
JUN	60	68	60	64	67	67	66	66	62	64
JUL	70	69	73	71	69	69	68	72	71	70
AUG	67	66	72	72	71	69	72	67	69	69
SEP	61	59	63	59	57	62	58	57	58	59
OCT	52	49	40	45	49	50	52	51	52	49
NOV	41	35	39	39	39	31	38	37	36	37
DEC	26	34	33	34	33	24	32	29	35	31

*Monthly values represent averages of the monthly mean temperatures over all five stations

**1967-1975 9-Year Average

Stations Used:

1) Boulder
2) Brighton 1/67 through 12/74; Cherry Creek 1/75 through 12/75.
3) Denver City
4) Denver AP
5) Evergreen

Table 8.3. Monthly Mean* Temperature for Houston AOCR (^{o}F)

	1967	1968	1969	1970	1971	1972	1973	1974	1975	AVG.**
JAN	53	52	55	48	57	57	49	56	57	54
FEB	54	50	56	55	57	56	52	57	56	55
MAR	66	58	56	59	61	65	65	67	62	62
APR	75	70	68	71	68	72	65	69	68	70
MAY	76	76	75	73	75	74	74	77	76	75
JUN	82	80	80	80	81	81	79	80	80	80
JUL	82	81	85	83	82	81	83	82	82	82
AUG	81	83	84	84	80	82	81	82	81	82
SEP	77	78	79	80	78	81	80	75	76	76
OCT	71	72	73	69	73	71	74	71	70	68
NOV	63	60	62	59	62	56	68	61	62	61
DEC	55	55	57	62	61	53	55	54	54	56

*Monthly values represent averages of the monthly mean temperatures over all five stations.

**1967-1975 9-year average.

Stations Used:

1) Houston
2) Galveston
3) Port Arthur
4) Pierce 1
5) Angleton

Table 8.4. Monthly Mean* Temperature for Los Angeles AQCR (^{o}F)

	1967	1968	1969	1970	1971	1972	1973	1974	1975	AVG.**
JAN	55	55	56	55	54	52	52	52	55	54
FEB	58	60	53	59	55	57	56	56	55	57
MAR	58	60	56	58	58	60	54	56	55	58
APR	54	62	61	60	59	62	60	61	55	59
MAY	64	65	65	66	62	66	65	64	64	64
JUN	65	68	66	70	67	71	70	70	63	68
JUL	74	73	73	73	73	74	71	74	72	73
AUG	78	72	76	74	77	74	72	72	71	74
SEP	74	72	72	71	73	69	68	72	73	72
OCT	70	66	65	65	65	64	66	66	66	66
NOV	64	61	63	60	58	57	58	61	59	60
DEC	53	52	56	53	50	55	55	54	56	54

*Monthly values represent averages of the monthly mean temperatures over all five stations.

**1967-1975 9-year average

Stations used:
1. Long Beach
2. LAX
3. Tustin/Irvine
4. Pomona
5. Burbank

Table 8.5. Monthly Mean* Temperature for Phoenix AQCR (°F)

	1967	1968	1969	1970	1971	1972	1973	1974	1975	AVG.**
JAN	52	53	56	52	52	51	50	53	52	52
FEB	57	60	54	59	55	58	56	55	54	56
MAR	63	60	57	59	62	69	55	63	58	61
APR	62	66	68	63	66	69	65	69	61	65
MAY	75	76	78	78	72	76	79	77	74	76
JUN	82	85	83	86	84	86	86	90	84	85
JUL	90	88	91	93	92	92	90	89	90	91
AUG	89	84	92	90	86	87	90	88	89	88
SEP	83	83	85	80	83	83	83	84	84	83
OCT	74	73	69	68	67	70	73	74	72	71
NOV	65	60	60	61	59	56	61	61	61	60
DEC	49	50	54	52	50	51	55	50	54	52

*Monthly values represent averages of the monthly mean temperatures over all five stations.

**1967-1975 9-year average.

Stations Used:

1) Phoenix WB AP
2) Litchfield Park
3) Apache Junction
4) Ajo
5) Tucson WB AP

Table 8.6. Monthly Mean Temperature for Chicago Metropolitan Zone (°F)

	1967	1968	1969	1970	1971	1972	1973	1974	1975	AVG.°
JAN	29	24	21	18	20	23	30	28	29	25
FEB	22	24	30	26	29	27	31	30	29	28
MAR	38	44	34	34	35	34	45	40	35	38
APR	49	52	49	50	48	45	50	53	45	49
MAY	53	56	59	60	57	60	58	57	63	58
JUN	70	70	63	68	73	66	73	68	72	69
JUL	70	73	72	74	72	74	77	78	75	74
AUG	68	74	75	72	72	74	76	73	76	73
SEP	64	66	65	66	70	66	69	65	63	66
OCT	52	55	52	57#	62	52	61	56	59	56
NOV	37	41	38	41	42	39	44	44	49	42
DEC	30	28	29	31	36	28	31	34	33	31

Chicago Weather-Bureau Station No.2

#Chicago University data used from 11/70 through 12/75.

°1967-1975 9-year average

Table 8.7 Monthly Mean Temperature for Denver Metropolitan Zone (^{o}F)

	1967	1968	1969	1970	1971	1972	1973	1974	1975	AVG.[o]
JAN	34	30	35	31*	32	30#	27	24	32	31
FEB	35	34	35	39	31	36	36	35	31	35
MAR	43	41	32	34	38	45	40	43	37	39
APR	48	43	52	44	48	48	43	48	44	46
MAY	53	54	59	59	54	57	56	62	54	56
JUN	61	68	62	65	69	68	68	68	64	66
JUL	69	72	75	72	71	70	71	75	73	72
AUG	68	68	74	74	73	71	74	70	71	71
SEP	62	61	64	60	58	62	60	59	60	61
OCT	52	52	39	46	49	52	54	52	53	50
NOV	40	36	39	39	39	33	40	38	37	38
DEC	26	29	32	33	32	25	32	31	38	31

Denver Airport data used from 1/67 through 12/69.
*Denver WSFO data used from 1/70 through 12/71.
#Denver WSFO AP data used from 1/72 through 12/75.
[o]1967-1975 9-year average.

Table 8.8. Monthly Mean Temperature for Houston Metropolitan Zone (°F)

	1967	1968	1969	1970	1971	1972	1973	1974	1975	AVG.°
JAN	55	53	57#	49	58	56*	47	55	57	54
FEB	54	50	57	57	58	55	51	56	55	55
MAR	68	59	56	59	63	64	64	67	61	62
APR	76	71	70	72	68	71	65	67	68	70
MAY	76	76	75	73	75	74	73	77	76	75
JUN	83	80	81	81	81	81	79	80	80	81
JUL	82	82	85	84	84	80	83	83	82	83
AUG	81	84	86	84	81	80	80	82	81	82
SEP	78	79	81	81	80	80	78	75	75	79
OCT	70	74	74	69	74	70	72	71	70	72
NOV	64	60	61	59	63	55	67	60	60	61
DEC	55	56	57	62	62	52	54	55	53	56

Houston WB Airport data used for 1/67 through 12/68.
#Houston FAA Airport data used for 1/69 thorugh 12/71.
*Houston WS Airport data used for 1/72 through 12/75.
°1967-1975 9-year average.

Table 8.9. Monthly Mean Temperature for Los Angeles Metropolitan Zone (°F)

	1967	1968	1969	1970	1971	1972	1973	1974	1975	AVG.°
JAN	59	58	58	58	59	56	56	55	58	57
FEB	63	64	55	61	59	60	60	59	56	60
MAR	61	62	60	61	60	64	58	60	56	60
APR	56	64	64	61	62	64	63	65	56	62
MAY	67	66	67	67	64	68	66	66	63	66
JUN	66	69	67	70	69	72	72	72	66	69
JUL	76	75	74	75	74	78	72	74	72	74
AUG	79	74	77	76	79	77	74	72	72	76
SEP	75	73	72	74	75	72	70	73	74	73
OCT	72	69	67	68	67	67	69	68	66	68
NOV	67	63	65	63	60	62	60	64	61	63
DEC	56	56	59	57	53	58	60	56	57	57

°1967-1975 9-year average.

Data from Southern California Air Quality Management District (AQMD) headquarters, downtown Los Angeles.

The average monthly temperature ranges for the metropolitan zones and AQCR's of interest, while not directly available in the U.S. Climate Summary, were easily computed using the formula: RANGE = 2(MAXIMUM - MEAN). (Technically, the range is the difference between the maximum and minimum temperature. However, the quantity, 2(maximum-mean) is within one degree F of the true range and was employed in the interest of reducing data transcription expenses.) "range" is the difference between the monthly mean of daily maxima and the monthly mean of daily minima, "maximum" is the monthly mean of daily maxima, and "mean" is the arithmetic average of the monthly mean of daily maxima and the monthly mean of daily minima. Thus, the monthly range statistics measure the spread between the average daily maximum and minimum temperatures. A monthly range defined in this manner is equivalent to the monthly mean of individual daily temperature ranges (daily maximum - daily minimum), since the same statistics are summed in the computation of both averages. Tables 8.10 through 8.14 present the average temperature range data for the Chicago, Denver, Houston, Los Angeles, and Phoenix AQCR's, while Tables 8.15 through 8.18 list the analogous data for the corresponding metropolitan zones (except Phoenix).

Because this task item dealt with the collection and summarization of measured data instead of estimates or results of questionnaire surveys, the reliability of the results is high. The only potential bias is that the five chosen weather stations within each AQCR may not accurately reflect its average climate. However, since a representative cross-section of sites was selected, any bias should be minimal. Further, daily minimum and maximum temperature measurements

tend to be accurate, hence, there should be no significant measurement errors in the data.

Table 8.10. Monthly Average Range[1] of Temperatures for Chicago AQCR (°F)

	1967	1968	1969	1970	1971	1972	1973	1974	1975	AVG.[2]
JAN	18	16	14	16	16	18	16	12	14	15.6
FEB	18	18	12	20	16	16	12	16	12	15.6
MAR	14	22	20	14	18	18	16	16	16	17.1
APR	18	22	22	18	24	20	16	22	18	20.0
MAY	20	20	22	22	26	24	18	20	20	21.8
JUN	20	20	20	20	24	22	20	18	20	20.4
JUL	22	18	16	20	22	20	18	20	20	19.6
AUG	20	20	20	20	22	18	20	18	18	19.6
SEP	20	18	16	18	20	18	16	22	18	18.4
OCT	18	18	18	20	22	16	20	22	24	19.8
NOV	14	14	10	16	20	8	14	14	18	14.2
DEC	14	14	12	18	14	14	12	10	12	13.3

STATIONS USED

1) Chicago WB City #2 1/67→10/70; Chicago U. 11/70→12/75
2) O'Hare Field
3) Waukegan
4) Aurora
5) Park Forest

[1]Calculated from formula below; [Data from U.S. Environmental Data Service Climatological Data Summary]:

$$RANGE_{AVG.} = 2(MAX_{AVG.} - AVG_{AVG})$$

[2]1967-1975 9-Year Average

Table 8.11. Monthly Average Range[1] of Temperatures for Denver AQCR (°F)

	1967	1968	1969	1970	1971	1972	1973	1974	1975	AVG.[2]
JAN	30	30	28	26	28	32	30	32	30	29.6
FEB	30	26	28	30	26	32	28	28	30	28.7
MAR	32	30	26	24	28	30	22	30	26	27.6
APR	30	24	28	26	26	26	24	28	32	27.1
MAY	28	22	26	32	26	26	24	36	32	28.0
JUN	30	30	24	30	34	30	32	32	32	30.4
JUL	30	32	30	30	30	32	30	32	30	30.7
AUG	30	30	32	30	30	28	30	32	28	30.0
SEP	30	34	34	30	30	28	28	32	32	30.9
OCT	32	38	22	28	30	28	34	30	36	30.9
NOV	24	26	28	26	28	26	28	28	30	27.1
DEC	28	22	26	28	26	34	28	28	30	27.8

STATIONS USED

1) Boulder
2) Brighton/Cherry Creek
3) Denver City
4) Denver AP
5) Evergreen

[1]Calculated from formula:

$$RANGE_{AVG.} = 2(MAX_{AVG.} - AVG_{AVG})$$

[2]1967-1975 9-Year Average

Table 8.12. Monthly Average Range[1] of Temperatures for Houston AQCR (°F)

	1967	1968	1969	1970	1971	1972	1973	1974	1975	AVG.[2]
JAN	16	14	16	18	20	20	20	18	16	17.6
FEB	20	18	16	20	22	20	22	16	20	19.3
MAR	18	18	16	18	24	16	16	16	18	17.8
APR	14	16	18	14	18	18	16	18	14	16.2
MAY	14	14	16	16	16	20	18	16	16	16.2
JUN	16	14	16	16	18	16	16	18	14	16.0
JUL	16	16	14	16	18	16	16	20	18	16.7
AUG	16	18	18	18	18	18	16	14	18	17.1
SEP	16	16	20	14	16	16	14	16	18	16.2
OCT	20	20	18	20	18	20	18	20	22	19.6
NOV	18	20	20	22	22	18	20	18	22	20.0
DEC	18	18	20	20	16	20	22	20	18	19.1

STATIONS USED

1) Houston
2) Galveston
3) Port Arthur
4) Pierce 1
5) Angleton

[1]Calculated from formula:

$$RANGE_{AVG.} = 2(MAX_{AVG.} - AVG_{AVG})$$

[2]1967-1975 9-Year Average

Table 8.13. Monthly Average Range[1] of Temperature for Los Angeles AQCR (°F)

	1967	1968	1969	1970	1971	1972	1973	1974	1975	AVG.[2]
JAN	24	24	16	18	24	26	22	20	28	22.4
FEB	30	22	18	24	24	22	20	28	20	23.1
MAR	20	24	24	22	22	22	18	20	20	21.3
APR	20	26	20	22	24	22	24	26	20	22.7
MAY	26	20	20	22	18	20	22	18	18	20.4
JUN	20	22	16	16	20	16	24	24	26	20.4
JUL	24	24	22	24	26	24	22	20	22	23.1
AUG	24	24	26	24	24	22	22	22	24	23.6
SEP	18	24	22	28	24	24	22	24	24	23.3
OCT	28	24	26	24	28	22	26	20	22	24.4
NOV	22	24	26	22	22	26	22	28	28	24.4
DEC	22	26	24	20	22	20	26	24	26	23.3

STATIONS USED

1) Long Beach
2) LAX
3) Tustin/Irvine
4) Pomona
5) Burbank

[1]Calculated from formula:

$$RANGE_{AVG.} = 2(MAX_{AVG.} - AVG_{AVG})$$

[2]1967-1975 9-Year Average

Table 8.14. Monthly Average Range[1] of Temperatures for Phoenix AQCR (°F)

	1967	1968	1969	1970	1971	1972	1973	1974	1975	AVG.[2]
JAN	30	26	22	28	30	32	24	24	26	26.9
FEB	32	26	26	30	30	34	22	30	28	28.7
MAR	30	28	30	26	34	34	22	28	28	28.9
APR	32	30	30	32	32	34	30	30	28	30.9
MAY	32	32	32	34	32	34	30	32	32	32.2
JUN	28	34	32	32	32	28	32	32	32	31.3
JUL	26	28	26	26	28	28	28	24	26	26.7
AUG	26	28	26	26	24	28	28	28	30	27.1
SEP	26	30	28	28	30	30	32	24	26	28.2
OCT	32	32	30	30	26	22	34	22	30	28.7
NOV	28	26	26	32	28	26	26	26	30	27.6
DEC	22	28	26	28	24	24	28	24	26	25.6

STATIONS USED

1) Phoenix WB AP
2) Litchfield Park
3) Apache Junction
4) Ajo
5) Tuscon WB AP

[1]Calculated from formula

$$RANGE_{AVG.} = 2(MAX_{AVG.} - AVG_{AVG})$$

[2]1967-1975 9-Year Average

Table 8.15. Monthly Average Range[1] of Temperatures for Chicago Metropolitan Zone (°F)

	1967	1968	1969	1970	1971	1972	1973	1974	1975	AVG.[2]
JAN	14	14	14	14	14	14	12	6	12	12.7
FEB	16	18	8	16	14	14	10	10	8	13.8
MAR	12	16	16	10	18	18	16	14	14	14.9
APR	14	16	16	14	24	22	12	18	12	16.4
MAY	16	16	18	20	24	24	14	16	20	18.7
JUN	14	16	16	18	28	20	18	16	20	18.4
JUL	16	14	14	16	20	18	18	14	22	16.9
AUG	14	14	14	14	20	16	20	16	16	16.0
SEP	12	14	12	12	18	14	16	14	14	14.0
OCT	14	14	14	-	20	12	14	16	16	15.0
NOV	10	10	12	14	16	6	12	8	14	11.3
DEC	14	12	8	16	16	8	6	6	10	10.7

[1]Calculated from formula:

$$RANGE_{AVG.} = 2(MAX_{AVG.} - AVG_{AVG})$$

[2]1967-1975 9-Year Average

Table 8.16. Monthly Average Range[1] of Temperatures for Denver Metropolitan Zone (°F)

	1967	1968	1969	1970	1971	1972	1973	1974	1975	AVG.[2]
JAN	30	28	30	28	28	32	26	28	28	28.7
FEB	30	26	30	34	24	32	24	28	28	28.4
MAR	32	30	26	24	32	32	20	32	26	28.2
APR	32	30	30	28	32	30	24	28	28	29.1
MAY	26	30	26	34	24	28	24	34	28	28.2
JUN	24	34	24	30	34	30	32	32	32	30.2
JUL	26	28	28	30	30	32	32	32	28	29.6
AUG	30	28	30	26	32	28	34	32	30	30.0
SEP	32	32	30	30	28	28	24	34	30	29.8
OCT	34	28	22	28	32	28	32	30	34	29.8
NOV	32	24	28	28	30	26	26	26	28	27.6
DEC	30	30	28	34	28	26	26	26	24	28.0

[1]Calculated from formula:

$$RANGE_{AVG.} = 2(MAX_{AVG.} - AVG_{AVG})$$

[2]1967-1975 9-Year Average

Table 8.17. Monthly Average Range[1] of Temperatures for Houston Metropolitan Zone (°F)

	1967	1968	1969	1970	1971	1972	1973	1974	1975	AVG.[2]
JAN	22	16	16	14	20	22	18	18	18	18.2
FEB	26	22	16	16	20	24	24	28	26	22.4
MAR	20	22	18	16	18	24	20	18	22	19.8
APR	18	18	18	14	20	22	18	22	18	20.9
MAY	20	18	18	16	18	20	22	18	20	18.9
JUN	20	16	20	18	20	20	18	22	18	19.1
JUL	20	16	20	16	24	20	22	22	20	20.0
AUG	18	18	18	20	18	22	18	18	22	19.1
SEP	16	18	20	12	14	18	18	16	24	17.3
OCT	24	20	18	18	16	22	20	22	26	20.7
NOV	20	22	24	22	18	20	24	22	26	22.0
DEC	18	20	20	20	12	24	26	22	22	20.4

[1]Calculated from formula:

$$RANGE_{AVG.} = 2(MAX_{AVG.} - AVG_{AVG})$$

[2]1967-1975 9-Year Average

Table 8.18. Monthly Average Range[1] of Temperatures for L.A. Metropolitan Zone (°F)

	1967	1968	1969	1970	1971	1972	1973	1974	1975	AVG.[2]
JAN	22	20	14	14	20	20	20	16	20	18.4
FEB	24	16	14	18	20	20	16	22	16	18.4
MAR	16	22	20	16	20	18	16	14	14	17.3
APR	16	18	16	18	18	20	18	18	14	17.3
MAY	18	14	14	18	14	18	16	14	14	15.6
JUN	16	24	12	16	16	18	20	20	14	17.3
JUL	20	18	16	20	18	22	20	18	20	19.1
AUG	18	18	20	20	18	20	16	16	18	18.2
SEP	14	18	16	22	18	18	16	18	18	17.6
OCT	16	18	18	18	22	18	22	14	18	18.2
NOV	16	18	20	18	20	22	16	20	22	19.1
DEC	18	20	16	18	16	22	18	20	22	18.9

[1]Calculated from formula:

$$RANGE_{AVG.} = 2(MAX_{AVG.} - AVG_{AVG})$$

[2]1967-1975 9-Year Average

8.1 REFERENCES

1. Environmental Data Service, U.S. Climatic Data Summary, National Oceanic and Atmospheric Administration, Vol.
1966 through 1975.

9.0 ABSOLUTE HUMIDITY

Virtually all humidity data archived by the National Weather Service (NWS) or the National Oceanic and Atmospheric Administration (NOAA) are expressed as percent relative humidity and must be converted to absolute humidity for this task item. As explained below, data on station barometric pressure, ambient air temperature, and relative humidity are required for the computation of absolute humidity.

Data were obtained from the National Climatic Summary publication [1]. Other sources, such as National Climatic Center (NCC) data tapes and the Climatlogical Atlas [2] were considered too cost prohibitive or were of insufficient resolution to be of any use.

Using the relative humidity , station barometric pressure , and temperature data from the summaries, one can calculate absolute humidity, using the relation: [3]

$$H = \frac{43.478 - RA \cdot PD}{PB - (PD \cdot RA/100)} \qquad (1)$$

where "H" is the absolute humidity, expressed in grains of water per pound of dry air; "P" is the station barometric pressure (not adjusted to sea level); "RA" is the relative humidity, expressed in percent, and "PD" is the saturation vapor pressure of water at the given air temperature. PB and PD must be expressed in the same units.

The monthly mean absolute humidity values calculated using the above expression are listed in Tables 9.1 through 9.5, which apply to Chicago, Denver, Houston, Los Angeles, and Phoenix, respectively.

Since the spatial coverage of the humidity data is only fair, it was not feasible to compute separate humidity statistics for the metropolitan zones within the AQCR's. Therefore, the single set of humidity statistics presented for each region is assumed to apply both to the metropolitan zone within AQCR there. If more detailed data were available, it would be possible to compute separate statistics for the AQCR's and metropolitan zones. However, the differences between corresponding metropolitan zone and AQCR humidities are not likely to be significant, because of the high internal consistency among absolute humidity readings within any given region.

A possible objection to the above procedure for computing monthly average absolute humidity is that it is not rigorous. The relative-to-absolute humidity conversion formula strictly applies only to simultaneous instantaneous temperature, humidity, and pressure readings, rather than to averaged statistics, while the monthly average absolute humidities listed here were computed directly from the monthly average relative humidity, pressure, and temperature. A more rigorous approach would be to convert each individual relative humidity reading to absolute humidity (using its corresponding temperature and pressure readings) and then to average these individual humidity values. To estimate the magnitude of the error introduced by using only monthly data in the computation, we ordered one NCC data tape, for Los Angeles, 1970 through 1975. The monthly average absolute humidities for those years were then computed from the individual temperature, pressure, and relative humidities (using equation 1) and were compared to Table 9.4. A dependent t-test yielded a result of 1.48 with 11 degrees of freedom, demonstrating that the difference between the two sets of mean

TABLE 9.1 ABSOLUTE HUMIDITY IN GRAINS OF WATER PER POUNDS OF DRY AIR*
MONTHLY AVERAGES FOR THE PERIOD 1967 THRU 1975
CHICAGO

	1967	1968	1969	1970	1971	1972	1973	1974	1975	AVERAGE
JANUARY	16.2	13.9	12.1	10.1	9.8	11.7	16.4	15.6	17.5	13.7
FEBRUARY	10.0	11.1	16.8	17.7	15.9	13.8	17.9	15.7	15.5	14.9
MARCH	24.5	23.9	17.4	22.1	20.3	19.6	33.9	24.7	19.3	22.9
APRIL	36.2	35.6	35.8	35.9	27.8	33.4	36.0	35.9	27.4	33.8
MAY	37.6	46.4	48.9	56.3	40.1	55.8	46.5	47.6	54.9	48.2
JUNE	78.4	72.5	62.4	74.4	82.7	58.2	77.6	61.4	85.6	72.6
JULY	79.5	79.8	90.9	84.5	75.7	83.0	88.5	81.6	86.5	83.3
AUGUST	71.5	87.4	82.9	81.1	83.2	92.9	93.6	78.6	98.7	85.5
SEPTEMBER	58.2	66.6	64.6	69.3	77.7	71.4	69.9	51.1	54.8	64.9
OCTOBER	39.4	42.3	39.0	44.2	59.4	40.2	53.3	39.1	42.1	44.3
NOVEMBER	23.8	28.8	25.7	27.3	27.2	26.8	2.8	29.4	34.5	25.1
DECEMBER	20.6	16.7	16.9	17.6	24.2	16.6	17.4	21.6	19.4	19.0
YEARLY AVERAGE	41.3	43.8	42.8	45.1	45.3	43.6	46.2	41.8	46.3	44.0

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* RELATIVE HUMIDITY, STATION PRESSURE, AND TEMPERATURE DATA WERE TAKEN FROM U.S. ENVIRONMENTAL DATA SERVICE, CLIMATOLOGICAL DATA, NATIONAL SUMMARIES.
ABSOLUTE HUMIDITY WAS CALCULATED USING THE FOLLOWING FORMULA:

H=((43.478)RA*PD)/(PB-(PD*RA/100))

WHERE

H= ABSOLUTE HUMIDITY (GRAINS WATER/POUND DRY AIR)
RA= % RELATIVE HUMIDITY
PB= BAROMETRIC PRESSURE (MILLIMETERS OF MERCURY)
PD= SATURATED VAPOR PRESSURE (MILLIMETERS OF MERCURY AT AMBIENT DRY BULB TEMP)

SOURCE: FEDERAL REGISTER, VOL.40, NO. 126, PAGE 27626

TABLE 9.2 ABSOLUTE HUMIDITY IN GRAINS OF WATER PER POUNDS OF DRY AIR*
MONTHLY AVERAGES FOR THE PERIOD 1967 THRU 1975
DENVER

	1967	1968	1969	1970	1971	1972	1973	1974	1975	AVERAGE
JANUARY	19.4	16.5	21.8	17.2	18.4	16.3	14.5	13.9	16.1	17.1
FEBRUARY	18.4	21.5	19.9	19.9	19.1	20.4	19.4	18.9	16.3	19.3
MARCH	23.7	22.9	21.3	22.8	22.0	24.3	24.7	24.9	21.0	23.1
APRIL	29.0	26.7	35.7	25.5	32.7	34.9	25.4	29.1	26.4	29.5
MAY	45.3	41.1	52.7	41.8	46.7	46.7	39.5	39.3	39.4	43.6
JUNE	69.6	52.8	58.1	57.9	56.2	72.6	47.0	54.8	54.0	58.1
JULY	85.8	68.5	78.9	77.5	71.1	72.9	66.9	67.8	63.4	72.5
AUGUST	64.1	66.8	75.5	76.9	72.7	79.4	60.9	59.4	55.5	67.9
SEPTEMBER	49.8	48.0	60.1	49.3	47.6	58.0	49.0	43.3	39.9	49.4
OCTOBER	33.8	32.5	32.1	34.7	34.7	35.5	34.9	39.9	29.7	34.2
NOVEMBER	24.1	23.4	25.7	27.5	25.0	20.6	25.1	23.8	21.7	24.1
DECEMBER	15.5	15.6	21.1	19.8	19.7	12.7	18.6	16.8	22.7	18.1
YEARLY AVERAGE	39.9	36.4	41.9	39.2	38.8	41.2	35.5	36.0	33.8	38.1

* RELATIVE HUMIDITY, STATION PRESSURE, AND TEMPERATURE DATA WERE TAKEN FROM U.S. ENVIRONMENTAL DATA SERVICE, CLIMATOLOGICAL DATA, NATIONAL SUMMARIES.
ABSOLUTE HUMIDITY WAS CALCULATED USING THE FOLLOWING FORMULA:

$$H=((43.478)RA*PD)/(PB-(PD*RA/100))$$

WHERE
H= ABSOLUTE HUMIDITY (GRAINS WATER/POUND DRY AIR)
RA= % RELATIVE HUMIDITY
PB= BAROMETRIC PRESSURE (MILLIMETERS OF MERCURY)
PD= SATURATED VAPOR PRESSURE (MILLIMETERS OF MERCURY AT AMBIENT DRY BULB TEMP)
SOURCE: FEDERAL REGISTER, VOL.40, NO. 126, PAGE 27626

TABLE 9.3 ABSOLUTE HUMIDITY IN GRAINS OF WATER PER POUNDS OF DRY AIR*
MONTHLY AVERAGES FOR THE PERIOD 1967 THRU 1975
HOUSTON

	1967	1968	1969	1970	1971	1972	1973	1974	1975	AVERAGE
JANUARY	42.4	45.5	50.2	36.5	51.6	51.3	39.5	54.5	54.0	47.3
FEBRUARY	41.2	35.3	51.9	44.1	43.4	48.3	44.7	43.2	50.0	44.7
MARCH	73.3	55.3	45.9	52.8	49.4	65.3	70.6	75.3	61.0	61.0
APRIL	105.4	84.0	83.1	82.5	67.9	85.9	72.7	72.6	80.8	81.7
MAY	97.9	117.4	101.6	91.0	94.9	96.3	90.9	107.1	108.0	100.6
JUNE	119.2	125.4	117.8	109.7	114.9	122.3	124.8	104.4	119.2	117.5
JULY	123.4	127.3	137.7	120.8	122.4	126.0	136.4	119.7	126.6	126.7
AUGUST	118.2	130.0	130.4	125.1	123.7	126.0	132.5	126.9	128.3	126.8
SEPTEMBER	102.0	107.2	112.1	120.6	121.3	129.4	125.1	103.1	98.3	113.2
OCTOBER	75.5	77.3	85.3	77.3	97.5	89.2	95.6	91.1	81.5	85.6
NOVEMBER	62.7	52.3	54.3	49.8	59.2	49.3	77.6	60.3	57.6	58.1
DECEMBER	49.2	42.5	51.7	60.8	63.5	45.7	44.6	49.2	42.7	50.0
YEARLY AVERAGE	84.2	83.3	85.2	80.9	84.2	86.3	87.9	84.0	84.0	84.4

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* RELATIVE HUMIDITY, STATION PRESSURE, AND TEMPERATURE DATA WERE TAKEN FROM U.S. ENVIRONMENTAL DATA SERVICE, CLIMATOLOGICAL DATA, NATIONAL SUMMARIES.
ABSOLUTE HUMIDITY WAS CALCULATED USING THE FOLLOWING FORMULA:

$$H=((43.478)RA*PD)/(PB-(PD*RA/100))$$

WHERE
H= ABSOLUTE HUMIDITY (GRAINS WATER/POUND DRY AIR)
RA= % RELATIVE HUMIDITY
PB= BAROMETRIC PRESSURE (MILLIMETERS OF MERCURY)
PD= SATURATED VAPOR PRESSURE (MILLIMETERS OF MERCURY AT AMBIENT DRY BULB TEMP)
SOURCE: FEDERAL REGISTER, VOL.40, NO. 126, PAGE 27626

TABLE 9.4 ABSOLUTE HUMIDITY IN GRAINS OF WATER PER POUNDS OF DRY AIR*
MONTHLY AVERAGES FOR THE PERIOD 1967 THRU 1975
LOS ANGELES

	1967	1968	1969	1970	1971	1972	1973	1974	1975	AVERAGE
JANUARY	46.8	39.6	50.0	47.0	40.4	40.5	39.1	47.4	40.9	43.5
FEBRUARY	45.1	57.7	45.0	50.9	45.5	50.6	54.5	41.3	48.9	48.8
MARCH	52.5	45.9	45.9	53.3	49.2	59.4	47.1	57.2	49.4	51.1
APRIL	43.6	54.3	55.8	48.7	52.3	60.1	51.6	54.0	52.4	52.5
MAY	57.1	63.6	MISSING+	64.1	60.6	66.8	65.5	63.4	65.9	63.4
JUNE	66.0	71.1	72.3	73.6	74.0	77.6	75.5	74.6	72.7	73.1
JULY	85.7	78.8	82.0	82.0	85.2	82.3	81.0	86.1	79.3	82.5
AUGUST	89.8	78.2	90.5	83.1	97.1	91.0	84.1	87.9	82.0	87.1
SEPTEMBER	84.7	75.2	81.6	72.8	85.1	84.0	76.9	87.5	85.1	81.4
OCTOBER	65.5	71.7	63.9	63.8	55.9	68.6	67.8	74.6	68.2	66.7
NOVEMBER	67.1	56.3	49.8	55.2	52.1	50.3	52.8	57.6	47.8	54.3
DECEMBER	34.0	36.7	47.0	44.6	37.5	36.1	45.3	43.3	50.1	41.6
YEARLY AVERAGE	61.5	60.8	62.2	61.6	61.3	63.9	61.8	64.6	61.9	62.2

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* RELATIVE HUMIDITY, STATION PRESSURE, AND TEMPERATURE DATA WERE TAKEN FROM U.S. ENVIRONMENTAL DATA SERVICE, CLIMATOLOGICAL DATA, NATIONAL SUMMARIES.
ABSOLUTE HUMIDITY WAS CALCULATED USING THE FOLLOWING FORMULA:

$$H=((43.478)RA*PD)/(PB-(PD*RA/100))$$

WHERE
H= ABSOLUTE HUMIDITY (GRAINS WATER/POUND DRY AIR)
RA= % RELATIVE HUMIDITY
PB= BAROMETRIC PRESSURE (MILLIMETERS OF MERCURY)
PD= SATURATED VAPOR PRESSURE (MILLIMETERS OF MERCURY AT AMBIENT DRY BULB TEMP)
SOURCE: FEDERAL REGISTER, VOL.40, NO. 126, PAGE 27626

+ RELATIVE HUMIDITY DATA WERE UNAVAILABLE FOR LOS ANGELES, MAY 1969.

TABLE 9.5 ABSOLUTE HUMIDITY IN GRAINS OF WATER PER POUNDS OF DRY AIR*
MONTHLY AVERAGES FOR THE PERIOD 1967 THRU 1975
PHOENIX

	1967	1968	1969	1970	1971	1972	1973	1974	1975	AVERAGE
JANUARY	26.5	33.5	43.6	29.1	23.8	22.0	31.1	33.1	25.1	29.8
FEBRUARY	21.7	48.0	37.1	30.3	22.2	19.2	40.7	18.2	28.6	29.5
MARCH	29.8	43.6	31.9	44.7	18.7	24.0	41.0	35.5	31.4	33.4
APRIL	29.4	32.2	30.0	22.5	24.0	21.2	28.7	20.6	28.7	26.4
MAY	30.7	45.3	35.8	27.9	28.9	26.8	39.1	27.0	26.8	32.0
JUNE	49.4	40.6	39.9	37.0	33.7	57.2	43.2	37.3	31.2	41.0
JULY	87.7	79.3	77.2	71.7	66.1	67.9	71.0	78.2	82.8	75.8
AUGUST	79.3	78.6	88.7	92.8	97.9	74.5	65.6	66.0	62.7	78.4
SEPTEMBER	68.6	49.9	73.4	61.4	62.9	59.1	40.5	74.4	65.8	61.8
OCTOBER	43.3	25.4	39.9	38.2	45.1	69.2	32.8	66.4	39.7	44.4
NOVEMBER	42.8	38.5	40.1	29.9	32.9	39.3	35.1	42.7	27.0	36.5
DECEMBER	32.9	26.9	38.2	32.0	32.7	32.2	25.4	30.2	36.2	31.9
YEARLY AVERAGE	45.2	45.1	48.0	43.1	40.7	42.7	41.2	44.1	40.5	43.4

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* RELATIVE HUMIDITY, STATION PRESSURE, AND TEMPERATURE DATA WERE TAKEN FROM U.S. ENVIRONMENTAL DATA SERVICE, CLIMATOLOGICAL DATA, NATIONAL SUMMARIES.
ABSOLUTE HUMIDITY WAS CALCULATED USING THE FOLLOWING FORMULA:

$$H=((43.478)RA*PD)/(PB-(PD*RA/100))$$

WHERE
H= ABSOLUTE HUMIDITY (GRAINS WATER/POUND DRY AIR)
RA= % RELATIVE HUMIDITY
PB= BAROMETRIC PRESSURE (MILLIMETERS OF MERCURY)
PD= SATURATED VAPOR PRESSURE (MILLIMETERS OF MERCURY AT AMBIENT DRY BULB TEMP)
SOURCE: FEDERAL REGISTER, VOL.40, NO. 126, PAGE 27626

humidities is not statistically significant at the 90% confidence level. All observed disparities are smaller than the mesurement error of the data, which is equivalent to approximately 10 points of relative humidity.

Because of the good agreement between the two methods, there is little, if any, advantage to using the NCC data tapes to compute monthly average absolute humidity statistics.

9.1 REFERENCES

1. Environmental Data Service, National Climatic Summary, 1967 through 1975.

2. Environmental Data Service, "Climatic Atlas of the United States," June 1968, reprinted 1974 by National Oceanic and Atmospheric Administration; distributed by National Climatic Center, Asheville, N.C.

3. Federal Register, 40, 126, p 27626.